MYCOTAXON

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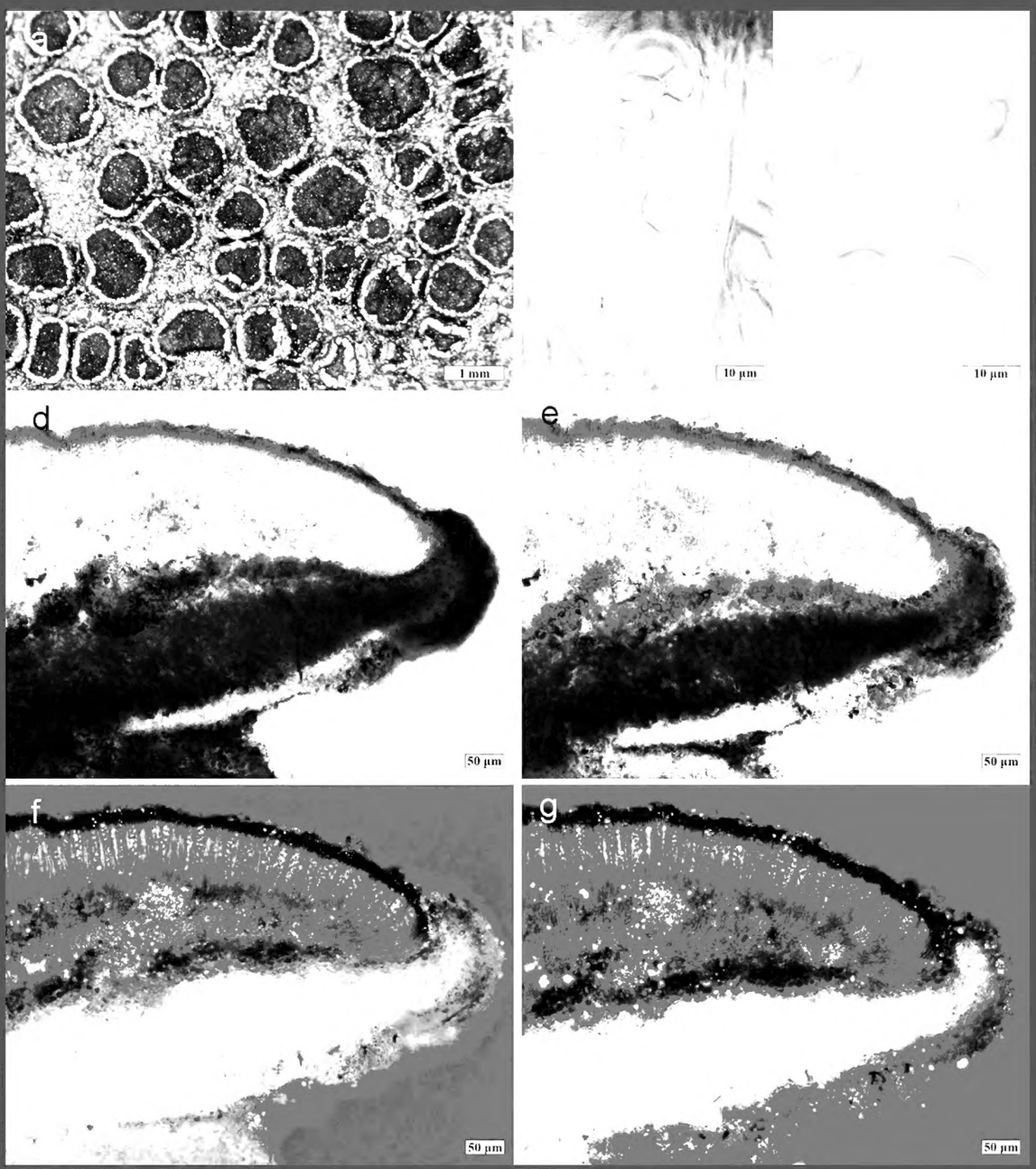
VOLUME 137 (3) JULY–SEPTEMBER 2022



Lecanora moniliformis sp. nov.
(Qiu & Lü— FIG. 1, p. 467)

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From the Editor-in-Chief

Mycotaxon 2023 editorial search— The current *Editor-in-Chief,* Lorelei Norvell, will retire after publication of Mycotaxon 137(4), the last 2022 issue, which has been delayed due to ill health (see below). Mycotaxon Ltd. and the Mycotaxon Editorial Advisory Board have made the difficult decision to place production of the journal on **hiatus** for the remainder of 2023, during which we will be looking for a new editorial team. If you have any suggestions or questions, please contact us at mycotaxon.hiatus@gmail.com Additional information and updates will be available on www.mycotaxon.com as they become available.

Mycotaxon 137(3) offers 19 contributions by 61 authors (representing 12 countries) as revised by 38 expert reviewers and the editors.

Petersen's highly entertaining history of the controversial American mycologist, William Gates Lloyd, who with his Dr. McGinty pilloried a generation of mycologists who dared segregate old genera to introduce new taxa, kicks off our seriously delayed 2022 July–September issue.

Seven papers in the new taxa section propose two new genera (*Callosus* and *Neoveronaea* from China) and seven species new to science representing *Astrothelium, Callosus, Lecanora, Neoveronaea* from China; *Dictyocheirospora* from India; *Didymium* from Mexico; and *Tilletia* from New Zealand.

Systematics presents three titles where different authors discuss *Mucor* species from Brazilian upland forest remnants (introducing the new name *M. septatiphorus* to replace *M. septata* nom. illeg.) and assign *Flosculomyces floridaensis* (newly recorded from Texas) to the *Zygosporiaceae* and *Albophoma* (based on analysis of *A. yamanashiensis* newly recorded from China) to *Ophiocordycipitaceae.*

In Nomenclature, Pennycook untangles the confusing genders assigned to genera with a *-trema* suffix (mistakenly assumed to be universally neuter).

The New ranges/hosts section (five titles) reports newly recorded species range extensions or hosts for [ascomycetes] *Erysiphe* (Pakistan) and *Hymenoscyphus* (Türkiye); [basidiomycetes] *Typhula* (Türkiye); and [lichenicolous fungi] *Chaetopyrena* (Ukraine) and *Cladophialophora, Nesolechia, Phacopsis, Punctelia, Sclerococcum, Scutula, Spirographa,* and *Zwackhiomyces* (India).

Mycotaxon 137(3) also provides identification keys to species in *Astrothelium, Callosus,* and *Chaetopyrena.* Papers providing conclusions supported by sequence analyses include three new species representing *Astrothelium, Callosus,* and *Neoveronaea;* two taxonomic reassignments (*Albophoma, Flosculomyces*), and three range extensions representing *Chaetopyrena, Erysiphe,* and *Hymenoscyphus.*

Our issue concludes with the announcement of two annotated species lists (to be posted on our mycobiota website following full editorial review) covering *Pucciniales* in Pakistan and airborne mycotoxigenic fungi in Poland and Türkiye.

The time has come — Two decades ago co-founder Dick Korf and the Mycotaxon Editorial Advisory Board appointed me to succeed Pavel Lizoň as *Editor-in-Chief*. The intervening twenty years, which have passed quickly and enjoyably, introduced many changes to the journal—annotated checklists moved from the print journal to Mycotaxon's mycobiota webpage, submissions prepared electronically replacing print-ready hard copy, introduction of a consistent style, all scientific names scrupulously checked by a *Nomenclature Editor* prior to publication, and in 2011 online publication. I greatly enjoyed corresponding with hundreds of authors from all over the world and had planned to continue as *Editor-in-Chief* for some time.

Unfortunately, health setbacks suffered during 2022—September's 'massive' pulmonary embolism and surgery for deep vein thrombosis, November's diagnosis and subsequent treatment of severe diverticulitis and gastrointestinal bleeding, December's (mercifully quick) bout of Covid-19, my continuing 22-year treatments for ovarian cancer—not only delayed this issue by six months but have proved too serious for me to even contemplate continuing to serve as *Editor-in-Chief* for the journal I truly love.

I regret not responding to most final submissions since September; my energy has focused entirely on preparing Mycotaxon 137(3). I also regret that as the Email folder containing all correspondence prior to 20 October 2022 was deleted from the editorial hard drive while I was in hospital, I must reassemble emails received prior to last November before preparing the 2022 October–December issue. I ask authors who have not yet heard from me please to remain patient and be certain to copy Shaun on all emails <PennycookS@landcareresearch.co.nz> .

Norvell & Pennycook will prepare one last Mycotaxon issue together — the '2022' October–December Mycotaxon 137(4), which will present **all** 2022-accessioned final submissions that have been approved by Shaun.

Warm regards,

Lorelei L. Norvell (*Editor-in-Chief*)
Shaun R. Pennycook (*Nomenclature Editor*)
22 March 2023

PUBLICATION DATE FOR VOLUME ONE HUNDRED THIRTY-SEVEN (2)

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Curtis Gates Lloyd: American mycological narcissist

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Abstract: Curtis Gates Lloyd, self-taught but knowledgeable amateur mycologist, wielded inordinate power through his self-supported publications during the period 1885–1925. His idiosyncrasies were exhibited also during his extensive travel and residence in Europe. Two subjects drew his ire to specific workers: 1) Lloyd concluded that the numbers of fungi were limited, especially the mycota of Europe versus North America, so what he considered an inflated number of taxa was unwarranted; and 2) the accepted and "legislated" custom of adding the names of authors following nomenclatural binomials, which Lloyd considered personal 'advertising.' While the number of victims was measured in scores, four recipients of Lloyd's criticisms are selected and summarized: Lee Oras Overholts, George Francis Atkinson, George Edward Massee, and Edward Angus Burt.

Key words: criticism, mycological history

Chapter 1. Introduction

It was during a period at the turn of the 20th century in which specimens of the world floras (including 'mycota,' a word as yet uncoined) were making their way to the botanical institutions of Europe's capitals. Most of Africa, much of Southeast Asia, and the large islands of the South Pacific were all colonies of a few European countries.

The mycological taxonomic literature of Europe was already largely codified, and the foreign specimens had to be collated into the prevalent outline. Following the early leaders (Persoon, Nees von Esenbeck, Link,

Batsch, Ehrenburg, Fries), Europe's larger fungi were thought to have been brought to order, but the American fungi were still largely uninvestigated. What species had been described had come from correspondents in America, submitted to mycologists in Europe. Chief among the Europeans was Miles Joseph Berkeley, a cleric associated with the Royal Botanic Gardens at Kew, a suburb of London. But in the United States during a brief period in the 1870–1890s, agriculture colleges and agricultural experiment stations had blossomed (Petersen 2019), and educational progress was becoming increasingly possible.

In the United States, two workers, both barely mycologically educated, were weaning the mycological community away from Europe: Charles Horton Peck, the State Botanist in Albany, New York, and Job Bicknell Ellis of Newfield, New Jersey. Peck not only collected, examined, and described many species he considered new but selflessly helped countless other aspiring amateurs. Ellis, conversely, amassed many specimens for distribution as sets ("exsiccati") to subscribers. Aside from a small handful of local publications of botanical and/or mushroom clubs, no professional journal in mycology was available. The closest items were PHYTOPATHOLOGY for a plant pathology audience of all stripes and JOURNAL OF MYCOLOGY, which at that moment was in a suspended state.

Two self-taught mycologists took their place in the US mycological community. Andrew Price Morgan (1836–1907) was a retired teacher who learned Latin in order to read the botanical literature from Europe while recuperating from some nervous disorders. He sent specimens to Peck and other workers and gradually felt able to publish on some mushroom genera. Curtis Gates Lloyd (1859–1926), introduced to fungi by Morgan, was a partner in Lloyd Brothers Pharmaceutical Company and used his wealth to publish both what he learned and what he conjured. Blackwell & Powell (1996) provide a good introduction to Lloyd's role in the mycological taxonomic community.

The ethics of scientific publishing were already in place: pre-publication manuscript reviews, often writing in the plural (the "royal 'we'"), gentle and circumspect criticism, and careful citation of previous literature. However, Lloyd was either ignorant of such things or set out to violate them. Using his personal funds, he published his own work for distribution to anyone who would send him specimens. Several of his iconoclastic innovations produced amusement for recipients, but he seemed unable to hold his pen in check. The victims of his pique reacted in their individual ways. The narration below selects four such workers and the arrows shot in their direction by Lloyd. In

Fig. 1. Curtis Gates Lloyd.
Stevenson & Cash (1936)

each case, a very brief (hopefully dispassionate) biography is followed by a narrative dealing with Lloyd's writings on that individual and his work.

Chapter 2. A sense of Lloyd

Marinus Anton Donk, a world-famous mycologist and nomenclaturalist, remarked to more than a few people that "he believed Lloyd set back North American mycology by 50 years because of his [Lloyd's] intimidation of its mycologists" (Burdsall & al. 2010; Petersen, pers. comm.).

Curtis Gates Lloyd (17 July 1859–11 November 1926; Fig. 1), native of northern Kentucky and apparently unschooled past high school, grew up appreciating the local flora. Learning his "simples" (medications compounded from local vegetation), he worked for the local pharmacy in Crittenden at 15 years old (Simons undated). At 18 he moved to Cincinnati, again working for a pharmacy for $5 per week. In 1886, he joined his two brothers to form Lloyd Brothers Pharmaceutical Company in Cincinnati.

Around 1890, Lloyd was introduced by A.P. Morgan to the study of fungi, a fascination that soon became Lloyd's major interest. By 1918 at age 59, he was able to withdraw from the family business to devote his entire attention to mycology. He used his continued liberal income from Lloyd Brothers for extensive travel and residences in the surroundings of the great herbaria of Europe and the cost of his own series of mycological publications. Unencumbered by reviewers and editors, he was able to (and did) express himself freely. Lloyd died in 1926 after being awarded an honorary D. Sci. from the University of Cincinnati that June (Fitzpatrick 1927; Simons undated).

In 1920 (his 61st year) Lloyd had been asked to submit an autobiographical sketch for use in a local newspaper and decided to reprint the brief sketch in his own journal (in the third person) [Lloyd 1920: 1025–1026]: "Mr. Lloyd is the owner of a fine farm, embracing about four hundred acres, near Crittenden, KY. Being a lover of flowers he devotes a large part of his time to the establishing of flowers in mass along the pike frontage of the farm. This farm will also be placed in the hands of a Trust Company to be maintained perpetually and a sufficient fund provided to take care of its expenses.

"Being an old bachelor and having very modest personal expenses, Mr. Lloyd has funds to devote to the maintenance of the [Lloyd] library [in Cincinnati, Ohio] and flower garden for the pleasure and profit of the public."

The following quote by Hesler (1975 see also Petersen 2019) stands as 'Exhibit A' demonstrating Lloyd's nonchalance: "Shortly after coming to Tennessee [1919], I took occasion to ship a few polypores and related things to [Lloyd].

He responded promptly, and asked for more, which I continued to send for some time. One hot September day, I had stopped overnight in Cincinnati, and went to see Mr. Lloyd at his herbarium. I found the place, stepped to the front door and rang the bell. I saw an older man sitting very close to, but with his back to the open door. He was attired in only blue-jeans and an undershirt, and no shoes. I continued to ring, but he seemed to pay no attention. Finally, the housekeeper answered with a 'ye-e-e-ess?' I said I wished to see Mr. Lloyd. She replied: 'Right here.' and pointed. Finally, I gave her my name, whereupon he wheeled around, greeted me heartily and then took me (he bare-footed) all over the herbarium.

"I asked what he intended to do with his enormous collection. He said: 'Some good institution will get it.'" That institution turned out to be the Smithsonian Institution and his collections now reside at the Department of Agriculture, Beltsville, Maryland.

"By any measure, Lloyd had a charitable vein. While considerable money was spent on his mycological pursuits, including extensive travel and the Lloyd Library and Lloyd Museum in Cincinnati, he also purchased, usually sub rosa, selected sites for public enjoyment. In the case of Woodland Park, in Kentucky, he (Lloyd 1915a) reproduced a short newspaper clipping, a footnote to which was self-explanatory: "Footnote: The above article, while not strictly mycological, will throw a sidelight on the character of the author of these letters, perhaps, not generally known to our readers."

Professor Harry Morton Fitzpatrick (1927) noted how Cornell benefited from Lloyd's quiet generosity: "The writer [Fitzpatrick] first met [Lloyd] when he came to Ithaca, in 1919, to examine the larger *Pyrenomycetes* in the Atkinson herbarium. Mr. Lloyd was much impressed by the natural beauty of Ithaca, and more especially by the richness of the fungus flora. We spent a pleasant week collecting with him and after he had gone, we learned that he had quietly and without ostentation purchased one of our favorite collecting grounds, an 800-acre tract of cold upland sphagnum bogs surrounded by wooded hills near MacLean, N.Y. It was thus preserved against grazing and logging operations and having been fenced and provided with a little laboratory building, it affords an ideal opportunity for field work in various phases of mycology. It is called the Lloyd-Cornell Reservation. Later, Mr. Lloyd purchased 436 acres of wild land nearby, at Slaterville Springs, designating it as a wildflower preserve. And shortly before his death he added a third, a pot-hole region in beech woods at Ringwood Hollow. Thus, three of the favorite collecting grounds at Cornell were preserved for future generations of students. All of these reservations were

placed by Mr. Lloyd in trust under the local management of a member of the biology staff of the Cornell faculty. He will long be regarded by local botanists as one of our most liberal benefactors."

To generosity must be added Lloyd's decidedly complicated personality. Hesler (1975): "That Lloyd had a sense of humor could hardly be disputed. At an AAAS meeting in Cincinnati, he showed up in the hotel lobby. He was showing all the professors a very unique cup-fungus. He had them all puzzled, even the discomycete specialists. Finally, it developed that his specimen was of clay — a model he had prepared for the occasion." Of course, Lloyd's prank was intended to show the fallibility and inadequacy of "the Professors," a persistent target through Lloyd's professional life.

To symbolize his harsh judgment of nomenclatural conventions, Lloyd introduced Tso Kay, a Buddhistic effigy. The symbol initially appeared without explicit explanation until Lloyd (1924a) provided a formal introduction: "Permit us to introduce Tso Kay [Fig. 2], the little god who's [sic] smiling face brightened the dead walls of London in recent years. I do not know what cult he originally represented. I understand a very worthy one, but there is behind his cheery countenance just a little hint of hypocrisy that symbolizes much of the work done in mycology. In these sheets he presents chiefly the cult of Kuntzeism and other name jugglers, who propose legions of 'new combinations' to which their own name is invariably added and pretend they do it under the obligations of priority. There is a lot of hypocrisy always in connection with name juggling.... Tso Kay will probably be kept busy in the future, and we hope his efforts will afford others as much amusement as he does the writer."

Regarding his tendency to take center stage, Lloyd (1917a: 6) wrote, "Prof. [Calvin Henry] Kauffman, whom I met in Sweden, told me that my writings impressed him that I wished to be the 'whole show.' I took no exception to it, for I have no doubt but that is the impression my writings had on him. I do not wish to be the 'whole show' for there is room for everybody."

In a personal letter, Dr. Josiah Lowe (23 October 1975, pers. comm.) wrote: "Certainly in print he was as abrasive as they come. At Kew I learned to my total surprise that in direct contact he was very, very different. He was very soft-spoken, very considerate, anything but the bull-in-the-china-shop we generally think of him. One story: Lloyd was an inveterate smoker. At Kew the rule is absolute – no smoking in the herbarium. Good rule, as the cases were wooden (guess they now have metal cases). Lloyd forgot once, was puffing away vigorously when he became conscious that there was a tremendous excitement going on, the staff running about saying something is on fire! Lloyd somehow

Fig. 2. Tso Kay.
Lloyd. Mycological Notes No. 72: 1267. 1924.

doused his cigar, fled to the backdoor and outside, and stayed away until the excitement subsided. Guess he told Miss Wakefield, who told me this story."

Lowe continued: "When you work through the Lloyd specimens and read the notes with the collection it is clear that Lloyd wasn't half as certain in actuality as he was with pen in hand. He died before I got into the polypores — I would have loved to have met him and consider myself very lucky that I got well-acquainted with Murrill and with Overholts before they died."

And then, there was the Osler vignette. In 1924b, Lloyd wrote: "It is probable, however, that I will not continue in this work much longer. But if I stop, I will turn it over to someone else. Another reason is my old eyes are wearing out and I cannot see things as clearly as one should, to decide many questions that

arise. I have, however, a pair of young eyes which I am training at Kew and will probably depend on them for help in this time. Another reason is I am an old man now [at 65], and my observations are [also], and I am well convinced, that most old men make fools of themselves, I cannot expect to be any exception to the general rule. I hope before the condition arrives, however, that some of my friends will get out the chloroform bottle, for *Osler was surely right* [his italics]."

By way of explanation, the Canadian physician Sir William Osler (1849–1919) and one of the four founding professors of Johns Hopkins University was a reputed practical joker. Osler was well known in the field of gerontology for the farewell speech he gave upon leaving Johns Hopkins to become the Regius Professor of Medicine at Oxford, England. 'The Fixed Period,' delivered in February 1905 (at 56 years of age), included some controversial ideas about old age. Osler, who reputedly had a well-developed humorous side, mentioned Anthony Trollope's The Fixed Period (1882), which envisaged a system in which men (no mention of women) retired at 67 and after being given a year at an idyllic "college" to settle their affairs, would be "peacefully extinguished by chloroform." Osler claimed that "the effective, moving, vitalizing work of the world is done between the ages of twenty-five and forty" and it was downhill from then on.

In an unpaged insert to Mycological Notes 74 (March 1925), Lloyd again communicated his thoughts on old age. Near his birthplace in Crittenden, Lloyd had a stone monument placed, similar to grave markers (Burdsall & al. 2010). Chiseled into the granite: "Born in 1859. Died 60 or more years after. The exact number of years, months and days he lived nobody knows and nobody cares. Monument erected by himself, for himself, during his own life, to gratify his own vanity. What fools these mortals be."

But this observation wasn't enough. In the same printed insert, Lloyd took the opportunity to throw another bomb. "The monument is first a burlesque on tombstones in general and second a satire on personal vanity, including the writer's and some other 'old gentlemen' he knows. The usual tombstone is a parody of the virtues and vital statistics of the deceased, of no possible interest to anyone else, and he is dead. Everyone is more or less vain and some so possessed with the idea, especially in their old age, that they are a nuisance to their friends and acquaintances. They seem to think that they are so important to the world, that when they die, the sun will stop, or if it does not stop, it will pause a little." This is followed by a paragraph on Lloyd's favorite shibboleth, too many "new species" and personal nomenclatural advertising. Finally: "The

monument was intended as a hit at all these forms of vanity and particularly a satire on one or two old gentlemen. One thinks that he is so learned that he can pass on questions of fungus history that he knows nothing whatsoever about, and never had the slightest opportunity to learn, and controverts the published conclusions of another who has had the opportunity and spent a lot of time trying to learn the straight of it. That may be vanity, too, but it is a fact. We can only add from the tombstone what Shakespeare or Puck or someone else says: WHAT FOOLS THESE MORTALS BE!! [caps his] Particularly Mycologists when they get past the Osler age."

Chapter 3. Lee Oras Overholts

Lee Oras Overholts (23 June 1890–10 November 1946; Fig. 3) was born in Camden, a small, rural hamlet in far-western Ohio. Although his early years and schooling have not been recorded, he attended nearby Miami University in Oxford, graduating in 1912 with A.B. degree. There he came under the mentorship of Professor Bruce Fink, an able and inspiring botanical teacher and lichenologist. Even as an undergraduate Overholts developed an interest in the 'pore fungi' and at the end of his junior year (Overholts 1911) he wrote and published his first paper entitled 'The known *Polyporaceae* of Ohio.'

During the spring of his senior year (1912), Overholts was recommended by Fink to assist J.C. Arthur's work with the rusts at Purdue University, which was where he first met Frank Kern, then an instructor. After graduating from Miami University, Overholts spent three years (1912–15) in graduate studies at Washington University (St. Louis). His continuing interest in the polypores was guided by association with Dr. Edward A. Burt (more below) of the Missouri Botanical Garden. Three important and extensive papers on the *Polyporaceae* followed (Overholts 1914, 1915a,b). After receiving his Ph.D. degree from Washington University in 1915, Overholts' previous association with Kern (by then department head at Pennsylvania State University) led to an offer of an instructorship at Penn State. In addition to numerous smaller publications, in 1936 he was a joint author of a botany textbook (Hill & al. 1936). At death, he left a book-length manuscript, The *Polyporaceae* of the United States, Alaska and Canada.

During his career at Penn State, Overholts was considered an excellent teacher and mentor. As his biographer (Kern 1948) reported: "All his life [Overholts] was a prodigious worker, not sparing himself in health or in illness. Nights, Sundays, holidays, and vacations were occasions for furthering the work so well begun during regular days and hours. However, he was also

an ardent trout fisherman and always looked forward to the opening of the hunting season."

Professionally, Overholts served the Mycological Society of America as Councilor, Vice President, and President. He was also a member of Sigma Xi, the Pennsylvania Academy of Science, the Torrey Botanical Club, and several honorary Greek-letter societies.

Kern (1948) wrote: "[Overholts'] last illness had kept him away from work only for a week. For the last five years his health was impaired but except for short periods he had kept tenaciously at his work."

In 1911 a mycological paper appeared in the Ohio Naturalist, written by the then unknown Lee Oras Overholts and purporting to be an annotated list of the polypore taxa reported to occur in Ohio. On his opening page, Overholts (1911) wrote: "The writer wishes to express his thanks to all who have aided in the preparation of the paper. Especial thanks are due to the Lloyd Brothers of Cincinnati, for free access to the literature contained in the Lloyd Library; to Mr. C.G. Lloyd for his determinations and verifications and for access to his excellent herbarium; to Mr. W.A. Murrill for determinations and verifications, and to Dr. Bruce Fink under whose direction the work has been done.

"The nomenclature followed is that of Mr. W.A. Murrill in his monograph of the family. The most generally used synonyms have been added to correlate this paper with other writings on the family." The 118 species were spread across 39 genera, a tempting target for Lloyd's pen. What was not written — Overholts was a 21-year-old junior undergraduate when he wrote the paper, encouraged by Dr. Bruce Fink, his mentor at Miami University.

Overholts' (1911) paper set off a series of derogatory comments published by Lloyd. Little criticism was aimed at the number of species accepted by Overholts, but Overholts followed (as he stated) the generic arrangement used by Murrill in his monograph of the family. In addition, the paper also accepted the rules of nomenclature adopted at the Brussels Botanical Congress in 1910, and Lloyd subsequently levelled his ire at the 'law-makers' at that Congress, including mycological delegates whose names read like a who's who of the science. A few of these attendees also became Lloyd's incessant targets. Overholts' (1914) second paper drew a more positive review by Lloyd (1915b), but Lloyd could not resist reminding his readers of his distaste for the previous paper, as follows: "…I am gratified that Mr. Overholts has gotten back to the realms of rational mycology. I presume that this is due to the

Lee Oras Overholts
June 23, 1890–Nov. 10, 1946

Fig. 3. Lee Oras Overholts.
Mycologia 40. 1948.

conservative influence of Professor Burt [Edward Angus Burt, graduate of Harvard, professor at Middlebury College and by 1915 on faculty at the Henry Shaw School of Botany at Washington University, St. Louis. More below]. In his previous paper he was no doubt influenced by Professor Bruce Fink, who does not know enough about fungus to form an opinion of the merits of such things, and Overholts' previous nomenclature was about as intelligible as a Chinese laundry ticket."

Josiah Lowe, successor to Overholts in his work on polypores, related to Dr. Marinus Anton Donk (who passed it on to me; pers. comm.) that Lloyd's scathing judgment on Overholts' (1911) early nomenclature caused a retreat by Overholts from internationally approved, formal, 'legislated' nomenclature as well as acceptance of numerous 'split genera' (i.e., *Hydnoporia, Fuscoporia, Fomitiporia, Fomitiporella,* etc.). Once burned, twice cautious. Overholts consequently adhered to shortened nomenclature and fewer genera for the rest of his career. Lloyd's words, which were not jocular, had wounded this young mycologist.

The Murrill polypore monograph cited by Overholts (1911) was a series of monographic treatments of numerous genera under the general title of The *Polyporaceae* of North America (Murrill 1902, 1903a,b,c,d, 1904a,b,c,d, 1905a,b,c, 1906). At least two ingredients ran afoul of Lloyd's self-generated code: 1) Murrill's recognition of multiple genera in the family and 2) his citation of each species binomial followed by its originating author of the epithet (in parenthesis) followed by the name of the worker who placed the species in the genus accepted by Murrill. The former, of course, was the opinion and discretion of any publishing worker, just as it is to this day. The latter was a fastidious adherence to the Code of Botanical Nomenclature (whether the prevailing international code of that day or the 'American Code,' a more explicit outline later largely adopted and merged into the International Code).

But Overholts was only a surrogate target for Mr. William Alphonso Murrill whose nomenclature Lloyd (1911) had written previously (more below). Under the heading 'History of the juggling' (transfer of a species from one genus to another followed by the name of the transferor, viewed by Lloyd as excessive 'advertising'): "And last but not least, our own Mr. Murrill made the remarkable discovery that [*Polyporus*] section *Ovinus* of Fries was the same as [genus] *Scutiger* in the sense of Paulet, and on the strength of this wonderful discovery wrote the name "Murrill" after each of the dozen (alleged) species that he considered." Footnote: "Paulet was one of the first

crude writers on fungus and did not have the most vague notion of their relationships. He [Paulet] included in *Scutiger* two polyporoids [sic], four hydnums [sic], and an agaric [sic]. How Mr. Murrill reached the conclusion that this misfit aggregation of Paulet's is the same as the section *Ovinus* of Fries we will leave to our readers to guess. It is beyond our comprehension."

Lowe's 1975 (pers. comm.) letter continues: "But much of Overholts' [later] conservatism was due to E.A. Burt, I'm sure. The work on Ohio polypores was a master's thesis under Bruce Fink, and Lloyd's blasts were aimed mostly overtly at Fink, whom Lloyd thought was totally ignorant of polypores. Burt would surely have reinforced any tendency Overholts had of reverting to old-style polypore taxonomy, and I at least give complete credit to Burt for the inclusion of microscopic data in Overholts' [next papers, which] give microscopic data for some species, and consistently did so in the later work."

Early the next year, Lloyd (1912) again took Murrill to task. "The last man to engage in this line of name changing is Mr. Murrill, who has no more trouble discovering 'new genera' and concocting new names than if there had not been three men doing exactly the same thing with the same plants before him. I question if there is an institution or mycologist in Europe that attaches any importance or pays any attention to this kind of work, and very few in America. In my opinion such work is of little value or avail."

By mid-1915, Lloyd was aware of Overholts' second paper on polypores, but Lloyd's (1915b) opinion of Murrill had not changed. "In quite recent years Murrill has published much. He has proposed so many new names and made so much confusion that no one pays much attention to them. At the present time young Overholts is doing much better work on the subject." Remember, this was 1915; in 1911, Overholts had followed Murrill's classification scheme before abandoning it in favor of a more conservative approach, no doubt helped considerably by Lloyd's initial attack.

The following year Lloyd again took aim at Overholts, but Overholts (1916b) had already been wounded and had changed his writing style (see extracts from Lowe letter above). Lloyd wrote: "It is extremely gratifying to me to be able to give a strong approval to a work issued on mycology. It is an excellent work. It is the first comprehensive and reasonably accurate account that has been given on the subject. Mr. Overholts has selected his names, in most instances, I think, with good judgment, and practically all are of established usage." There follow 1.5 pages of 'Discrepancies in Mr. Overholts' paper.'

In the same Mycological Notes in a mixed blessing for Overholts, Lloyd (1916a) again directed his aim at Murrill, here worth repeating. "A general alarm has been sent out by the New York Botanical Garden for four species of Agarics that mysteriously escaped having Murrill's name affixed in a recent issue of their publication. It was the intention to add the name of Murrill to all 111 species, but by some slip four got away. A liberal reward will be paid to anyone who will capture one of these mavericks and bring it back into the fold." The effect this may have had on Murrill is not known, although he continued to publish unabated.

Soon, Overholts changed his research interest to other botanical topics out of reach of Lloyd's pen, but his interest in the polypores never died. He gathered a book-length manuscript, complete with many photo illustrations until 1933. The task of putting the manuscript through the press fell to Josiah Lowe (Overholts 1967). In the preface, Lowe wrote: "The final draft of this manual was written by Dr. Lee Oras Overholts in 1933, after twenty years of work at Pennsylvania State College as the foremost American specialist in the *Polyporaceae.* Until his death in November 1946, at State College, he corrected the manuscript continuously as new information became known, though he made no overall revision. For six months before his death Dr. Overholts had been actively putting the manuscript in shape for publication, and, as left, it was substantially complete." The family *Polyporaceae* was spread across eight genera. In a forward to the second, unchanged edition, Alexander H. Smith included a list of the 43 genera and numerous species in the manuscript as arranged in the genera of the day (1967).

In the 23 October 1975 (pers. comm.) letter quoted above, Lowe related: "About a year before he died Overholts said to me that the taxonomy of the polypores needed revision, and that he thought the system proposed by Patouillard was the best available. I suspect he did not adopt it because, from about 1930 on, he was unable to make the sections and do the other work required to check the concepts. In 1944 when I was there [at Pennsylvania State University], his microscopic studies were secured by teasing out a minute piece of the hymenial areas with needles, taking ½-1 hour for each mount. Of course, I [Lowe] quickly fell into the routine of preparing sections for him of anything of mutual interest."

Overholts published a series of 13 papers, generally chronological and called 'Mycological Notes' (Fergus 1955). One must wonder whether they were innocently titled or, perhaps, intended to reference Lloyd's voluminous series of the same name.

Chapter 4. George Francis Atkinson

Born in the hamlet of Raisinville, Michigan, George Francis Atkinson (26 January 1854–14 November 1918; Fig. 4) was prepared in local schools. According to Dawson (2007), Atkinson told a group of students that he ran away from home at the age of 13, "barn-storming" all the way to South Dakota. Recognizing that an education was the key to personal progress, Atkinson returned home and at 24 years old took some remedial courses at Olivet College in 1878. After a short time, though, he transferred to Cornell University, where he took botany courses under Albert Nelson Prentiss and William Russel Dudley (Korf 1991, Petersen 2021) and in 1885 was awarded a B. Phil. (these days an A.B.). Instead of pursuing an advanced degree, Atkinson embarked on a tour of southern institutions, beginning with three academic years (1885–88) at the University of North Carolina. After a single academic year (1888-89) at the University of South Carolina he moved to a newly created position as Professor at the Alabama Agriculture and Mechanical Institution (now Auburn University) for three academic years (1889–92). His chief occupation centered on plant pathology throughout, but he did publish occasionally on much wider subjects, including entomology, zoology, ornithology, and botany.

Fresh from Alabama A&M (where he had been awarded an honorary M.A.), Atkinson returned to Cornell in 1892 as Assistant Professor of Botany. His duties were divided between the Liberal Arts campus in Ithaca and the Agricultural Experiment Station, some 50 miles to the north in Geneva. In 1896, upon the death of Albert Prentiss, Atkinson succeeded as Botany Department Head (in the College of Liberal Arts). Delayed by more immediate tasks, Atkinson (1897a) published the significant paper 'Some fungi from Alabama.' In its introduction he wrote: "In the determinations of the Basidiomycetes Mr. A.P. Morgan of Preston, Ohio, has from time to time given great aid and as well as Dr. Chas Peck of Albany, N.Y., and Mr J.B. Ellis of Newfield, N.J. to all of whom I wish to express my sincere gratitude." During his tenure as Botany Head, New York state established the State College of Agriculture at Cornell with a second department of botany (Petersen 2021), and the Liberal Arts Botany Department slowly waned, eventually to be disbanded. On a protracted collecting trip with students and assistants to the slopes of Mt. Rainier in 1918, the rest of the party returned to campus as the weather turned colder. During a storm Atkinson contracted influenza and died just a few days after the November 11 armistice ended World War I. Atkinson was elected to the National Academy of Sciences in 1918, and his life was celebrated widely (Fitzpatrick 1918, Farlow & al. 1919, Hesler 1975).

Almost as soon as Lloyd could express himself mycologically, he opined that America was in serious need of a popular book outlining the mushrooms (i.e., agarics) for the country. Lloyd (1899a) held C.H. Peck in high regard. He reported: "Prof. Chas. Horton Peck, of Albany, N.Y., has collected about fifty specimens in alcohol. Prof. Peck has been an active student of our native agarics [mushrooms and relatives] for upward of thirty years and has contributed more than all others together to our knowledge of these plants. We will recognize him as our authority on American agarics and to a set of authentic named specimens by him, we attach the greatest value. We appreciate the kindness all the more, as we feel that Prof. Peck himself does not place much value on alcoholic specimens."

As early as 1899 Lloyd (1899b) laid out his frustration. "Why can we not have a manual of Agarics? We believe that but one man in this country, Prof. Chas Peck, has a wide and critical knowledge of growing agarics, and, we hope, he can be induced to give us a manual."

However, as Peck demurred from such an activity, Atkinson first published a large bulletin from the Cornell Agricultural Experiment Station on the region's mushrooms (Atkinson 1897b), later expanding the bulletin into a book (Atkinson 1900, 1901). In one book review, Lloyd (1906) wrote: "Unfortunately there is no one book of much service. I always advise my correspondents to buy first Atkinson's 'Mushrooms, Edible, Poisonous, etc.' It is the best book we have. It is only a primer and does not consider one out of twenty of the agarics you will meet every season, but you can derive from it a general idea of classification. It is a difficult matter to get a 'start' in American mycology, and I have reason to know that Atkinson had a hard enough time to learn what he knew at the time he wrote the book. So I believe he should have all praise for what he has done, not hiding the fact that there is a great deal of room to do much better as he learns more of the subject."

Atkinson was easily offended and suffered from self-effacement (Hesler 1975; Petersen 2019). Having smarted from Lloyd's pen, he was further affronted when Lloyd (1907a) compared Atkinson's photographic illustrations with Emile Boudier's exquisite aquarelles. In response, Atkinson took pen in hand, writing to Lloyd: "I presume you know that the Library at Cornell at my instigation has been from the first a subscriber to Boudier's Plates for a complete set. When I was in Paris in 1903, I spent half a day looking through Boudier's original illustrations with him. I recognized in them at that time the finest illustrations of this character which I had ever seen. Added to Mr. Boudier's talent as an

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BY C. G. LLOYD.

No. 59.

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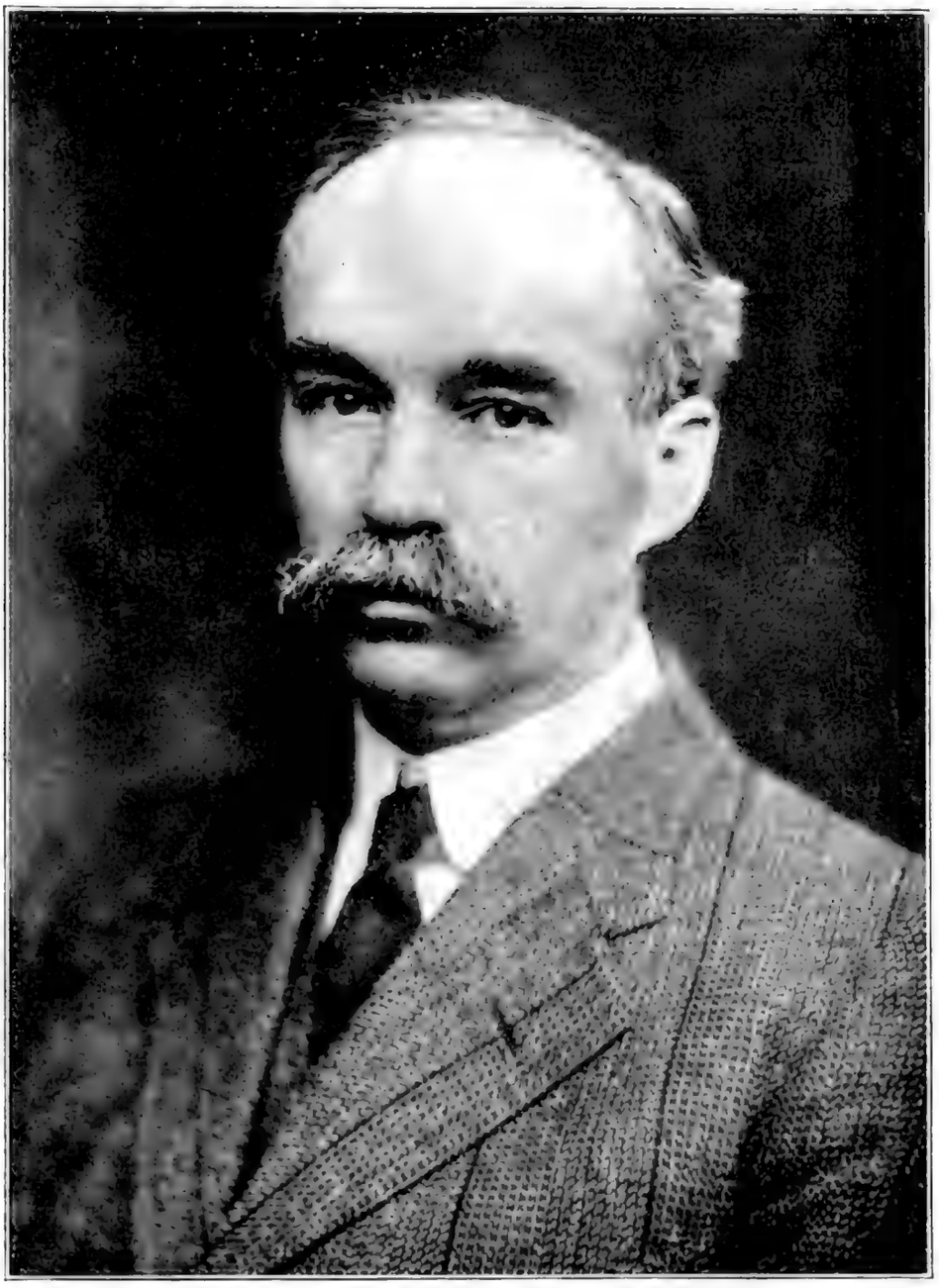

GEORGE F. ATKINSON

FIG. 4. George Francis Atkinson.
Lloyd. Mycological Notes No. 59. 1919.

artist, we have the work of a very careful scientific man in connection with accurate mechanical work in measuring and obtaining the exact proportions of the different parts of the plant. At that time, he told me his method was to obtain absolute accuracy of form and proportions. I regard them as the finest set of Mycological plates which have ever been published." In his opening sentence, I [RHP] detect some defensiveness. Did Atkinson perceive some unfairness in the comparison? A tirade would follow only three months later.

Lloyd (1907b) told the following story: "Mr. [William Henry] Long states that Atkinson's 'new genus' *Dictyobole* is based on *Simblum Texense,* and Mr. Long ought to know for it was he who sent Professor Atkinson the material on which the genus was based. It seems that when Long was a student at Cornell under Professor Atkinson he left him some eggs of a phalloid that developed into something that looked strange to Atkinson. He [Atkinson] drew a picture of it (that has no possible resemblance to the plant, see fig. 64 page 130) and on this figure the new species and genus '*Dictyobole Texense,* Atkinson and Long' was based. Long's name seems to have been added in the nature of a 'jolly' for he [Long] writes me [Lloyd] it was done without his knowledge or consent. It is an illustration, however, of the usual value of these advertising formulae as applied to 'science.' After the 'new genus' had been published, Mr. Long sent me some dried specimens and while I did not claim to know much about phalloids, I recognized that it was an old genus that was well known and well illustrated before Atkinson was born, and I thought it was probably an old species (*Simblum gracile* of Ceylon) as well. The whole story is illustrative of the troubles that are liable to overtake those who start out their search for new species before they learn the old genera."

In another book review, Lloyd (1909) wrote: "Atkinson's book, a few years ago, which was the first step in the right direction, was an immature publication. The author had not learned a great deal of his subject when he went into print and the result was a fragmentary account, good as far as it went, but it did not go very far. [Miron] Hard's [1908] book [see Petersen 2020] will supply much of this deficiency. "[Hard's] book is a practical demonstration of the value of photography in mycology, a fact, however, that was clearly demonstrated by Atkinson's book."

Lloyd was, if anything, consistent in his views. He later (Lloyd 1917a) wrestled a book review into a compounded put-down. "In this country we have nothing [in the way of mushroom books] whatever that is credible. Hard's book is a good representation of a few common species, but Hard never had any very extensive, critical knowledge of the subject. Marshall's book

[1905; see Petersen 2020] presents some very good photographs and figures, but the author of the text was woefully lacking in familiarity with the plants. A number of years ago Atkinson got a little preliminary idea of the subject by sending dried specimens to Bresadola and Morgan, but his book is more noteworthy for what it omits than what it includes. I am told that Atkinson, in the years that have intervened since he wrote his book, has steadily been working with the Agaric subject, and no doubt at the present time could make a better presentation of it. Let us hope for his own sake, as well as that of science, that he will not fail to do it.

"While I have written a good many 'tirades' on the subject, I would not have any of my readers believe that it is from any personal grievances. On the contrary, the mistakes, blunders, and personal foibles of mycological writers have been my chief source of pleasure. I do not know that I have made any enemies except Atkinson and was surprised lately to find that he had taken offense at some of my writings. I have always tried to be good natured in my comments, and as a general thing, I think the parties affected are taking it more as a joke on themselves and an idiosyncrasy of myself (with the exception of Atkinson)."

The nomenclatural rules under which Atkinson wrote were, even at that time, accepted in both Europe and the United States. Ironically, it was Atkinson who offered the motion to cite the originating author's name directly after the binomial (De Wildeman 1912; transl. RHP) at the Brussels Congress of 1910. But the principle had previously appeared in the "American Code of Botanical Nomenclature" (Sect. II, Art. 1.; Bull. Torrey Bot. Club 31: 249—261. 1904) which was distributed to the Vienna Congress of 1905, although not totally adopted there. Atkinson was actually correct, and future nomenclature codes would vindicate his usage. This as opposed to Lloyd, who followed only his own predilection.

Atkinson's death in 1918 (probably of 'Spanish flu') on the Mt. Rainier collecting trip did not assuage Lloyd, however. Some five years later, Lloyd (1923) lobbed yet another missile in Atkinson's direction.

Two decades earlier Atkinson [1902 J. Mycol. 8(3): 106] had published a new genus as '*Tremellodendron* Atk., n.g.' Lloyd claimed that he (Lloyd) had previously sent a specimen of this fungus to Bresadola, who advised him of its uniqueness. Lloyd was incensed at Atkinson's perceived breach of ethics but did not relate the story until well after Atkinson's death. Lloyd (1923) wrote: "As this was exactly what Bresadola had written me as to the same plant several years before, and I knew Atkinson was sending plants to Bresadola, I thought I could

see through his 'new genus.' I met [Atkinson] in Paris some years afterwards and charged him in a mild way of trading on Bresadola's knowledge. He denied it and stated that he (Atkinson) had made the discovery independently and that he had sent it to Bresadola with the statement as to its basidia, and his proposal to call it a 'new genus.' When I met Bresadola shortly afterward I told him what Atkinson claimed, and while Bresadola did not seem to be much exercised over it, not half as indignant as I was, he stated that Atkinson sent him the plant as I had sent it, as *Thelephora Schweinitzii* or *Thelephora pallida*, and that he [Bresadola] had written him as he wrote me, that it had globose cruciate basidia and that the plant was a *Sebacina*. Here was a direct contrary statement by two men, both of whom could not be true. Someone was handling the truth very carelessly and I never thought for a minute it was Bresadola. They criticize me because I hold that personal names should not be added to plant names, but when the system induces men to venture into the realm of falsehood and misrepresentation to justify their names it is high time it should be abolished. If the plain facts were set forth, I doubt if Atkinson knew that *Tremellodendron* had basidia until he was informed by Bresadola." The story was decorated with an effigy of Tso Kay.

Along these lines, Lloyd understood that the tremelloid genus *Sebacina* included both resupinate and non-resupinate forms. He used the fictional Dr. McGinty to jocularly propose the genus *Atkinsonia* to accommodate the non-resupinate forms. He wrote (Lloyd 1916b): "As to generic names it might be changed on a strict limitation of *Sebacina* to resupinate species, on the same principle that *Tremellodendron* was proposed, but I should consider it an artificial classification." (Stevenson & Cash 1936)

Chapter 5. George Edward Massee

The rural agricultural beginnings of 19th–20th century American mycologists has already been discussed (Petersen 2019; Rogers 1981), but the origins of George Edward Massee (30 December 1850 [Wikipedia cites 20 December 1845, death at 71; IF cites 1850, and 1917 Nature article cites "about 1850"]–16 February 1917; Fig. 5) may mirror this idea in England. Born in a rural hamlet of Scampston in East Yorkshire, not far from the North Sea, Massee was born to a family of farmers. Massee's biographer, Ramsbottom (1917), wrote: "It was intended that he should become a farmer as was his father, but, according to his own statement, he did very little good at farming. While working on the farm he became interested in wildflowers and in the larger fungi and drew and painted them. He was sent to the York School of Art, where he gained the

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BY C. G. LLOYD.

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PROFESSOR GEORGE MASSEE.

FIG. 5. George Edward Massee.
Lloyd. Mycological Notes No. 34. 1916.

national medal for the drawing of flowers from nature." His interest and talent were evident, but encouragement for continued studies came from Dr. Richard Spruce, a well-known botanist-explorer and cousin to Massee's mother, who was in a position to apply some financial lubrication to George's next steps.

Although Massee went into residence at Downing College at Cambridge, Spruce arranged an opportunity for Massee to travel to the West Indies and South America, ostensibly to collect and document orchids. The round trip was on French ships and in the company of Frenchmen and upon his return Massee and a few others joined the fabled (French) Foreign Legion to fight in the Franco-Prussian War. But using her position as mother of an only son, Massee's mother arranged to have him sent home to resume the family's farming.

Upon the death of his father, George and his mother gave up the farm and moved to Scarborough where he taught in public school for some years. During those years he painted many agarics which caught the eye of Mordecai Cubitt Cooke (1825–1914), who subsequently used many of them in his "Illustrations of British Fungi." In 1880 (at 25-30 years of age), Massee published his first paper, "Notes on some smaller fungi."

Mother and son again moved, this time to London and eventually to Kew. George became known as a public speaker on natural history and free-lanced in the Kew Herbarium. In 1891, he published a long paper on selected groups of fungi. In 1892–93, he worked at the British Museum but not in mycology or on herbarium tasks. 1892a saw the first volume of four, BRITISH FUNGUS FLORA. Together with a friend, they purchased Cooke's periodical, GREVILLEA, which had already lasted through 20 volumes. Under Massee's editorship, volumes 21 and 22 appeared, after which GREVILLEA ceased. In 1893, after Cooke retired from Kew, Massee was appointed Principal Assistant in Cryptogams.

Through all of this, Massee never lost interest in natural history and regularly attended and led forays, especially for fungi. In 1896, the British Mycological Society was founded and Massee was elected its first president, serving for two years. Over the next two decades he reinforced his reputation as the reigning mycologist in England, publishing numerous papers and several books. He retired from Kew in 1915 (probable age 65) and moved to Sevenoaks. In a biography not totally laudatory, Ramsbottom (1917) wrote: "Massee ranks with Berkeley and Cooke as one of the foremost mycologists of this country. He published over two hundred and fifty original papers."

A generation younger, George Edward Massee was a successor and protégée of Mordecai Cubitt Cooke (1825—1914). Cooke was multi-talented and an

entrepreneur, mycologist, artist/illustrator, and writer (Ramsbottom 1915). His published plates of "Illustrations of British Fungi" filled 12 volumes, and his books and papers were voluminous. He founded the journal GREVILLEA which, in time, he sold to Massee and a co-investor (Massee 1892b). Cooke was attached to the Royal Botanic Gardens at Kew, and Massee followed suit.

Lloyd was not enthusiastic with Cooke's writing or artistry (Lloyd 1915c). To Lloyd's mind, the writing represented quantity, not quality, and Cooke's illustrations were often artist's reconstruction of dried specimens in Kew's herbarium (Lloyd 1915c). Cooke's biographer (Ramsbottom 1915) passed on the quip: "A saying current among European mycologists is, that Cooke was so talented he could draw a picture of an agaric that he had never seen." Lloyd's opinion of Cooke's prodigious output was mixed, and his commentary on Massee's work seemed to start innocently at first but grew less appreciative over time.

Lloyd (1904), having spent 14 months in Europe with protracted stays in Kew, Paris, Uppsala, and Berlin, furnished very brief sketches of several workers he had met. Of those at Kew: "[George Massee] is a man I should say about fifty years, an excellent conversationalist and I am told a very entertaining public speaker." Both these attributes were said of Cooke as well. No judgement was offered as to the direction or quality of Massee's research. (That would come before long.)

The subscription price for receiving Lloyd's publications was the donation of specimens to Lloyd's 'Museum.' Each package was inspected and specimens identified. Almost always, the donor and his collections were mentioned in print. In this exchange, however, correspondents also made inquiries to be answered individually by Lloyd. Lloyd (1906) wrote that he was overwhelmed with correspondents' queries about available American mushroom books. Instead of answering each inquiry separately, Lloyd distributed a brief review of the available books. After Atkinson's and Marshall's books came Stevenson's book from England. Last, he wrote: "Massee's BRITISH FUNGUS FLORA, four volumes [Massee 1892a, 1893a,b, 1895], is the latest English work and is largely used in England. The arrangement of the genera departs from all other works, and it is so difficult to find anything in it that I rarely use it." His opinion of Massee then lay dormant, with a photo portrait and brief biographical sketch featured a bit later (Lloyd 1910).

Although Massee succumbed to influenza in February 1917 (Ramsbottom 1917), some months later Lloyd (1917b) divested himself of a few derogatory interactions he had had with selected mycologists in high places. The general

theme was to put these 'elites' in their place. The following is an example. "I told Massee once that Professor Burt said that his [Massee's] new genus '*Heterobasidium*' was a bull [an early 20th century word denoting speculation and/or deception], and days afterward he told me that he had no doubt that Burt was right. This was ten years ago, but he [Massee] never mentioned it in print to the day of his death. I asked Professor Burt if he intended to show it up, and he said he did, but in a 'nice way.' The following was his 'nice way:' My own study of the type of *Heterobasidium chlorascens* Massee, which is the type species of the genus, failed to locate any basidia whatever.'

"I readily concede that this is a nice way in dealing with this bull, but it impresses me also as being a very nice case of whitewash, and its treatment in this way only encourages others to 'take a chance' on such work. One cannot cure a cancer by applying a coat of soft soap. In those days Burt did a lot of indirect toadying to Massee. But recently, since Massee has been shown up in his true color by another [worker], and is dead, Burt comes out and calls him a promotor of myths. Burt is a brave man, when all danger is past."

Two birds with one stone. Far from being muzzled, Massee's written output was relatively prodigious, including at least three book-length works (Massee 1902, 1906, 1911).

Just as was Lloyd's opinion of Massee's idol, M.C. Cooke, Massee's oeuvre was judged harshly. Even his biographer (Ramsbottom 1917) wrote: "But though often brilliant, he [Massee] was often careless: if he had had any capacity whatever for taking pains, he would have been a genius. He had a clear mind and was regardless of authority: although he often totally disregarded results which would have prevented him reaching some other startling conclusions." Echoing Lloyd's opinion (Ramsbottom 1917): "[Massee] commenced when Berkeley was *facile princeps* [his italics] in British mycology; Cooke followed and then Massee naturally forged ahead on Cooke's retirement. But times were changing and though Massee's opinions in systematic questions received the consideration due to his extended knowledge, when he attempted to criticize—or even ridicule—branches of the subject in which he had obviously no practical experience, he did not add to his reputation. His cynicism often led him to say, or even to do, things which were much resented."

Even later, while superficially dealing with the work of Mr. Charles Crossland (1844–1916), Lloyd (1924c) confessed the following: "When we were in correspondence with Mr. Crossland for some years before his death, we are ashamed to admit that we had a kind of mental prejudice against him. We do not know exactly the reason for it. Perhaps because he was always

closely associated with Massee, and we could never see any good in Massee's work." And thus was Massee dismissed.

Chapter 6. Edward Angus Burt

Edward Angus Burt (9 April 1859–27 April 1939; Fig. 6), was an almost exact contemporary of C.G. Lloyd and, like Lloyd, was born on a farm. The family soon purchased a small dairy in Saratoga County, New York, not far from Albany, the state capital. In spite of the death of his father when he was five, his mother was able to maintain a few cows and brought in a small income from butter. As reported by Burt's biographer (Dodge 1979), farm chores left time for Edward to investigate the local environment both for table food and, incidentally, interesting plants ripe for naming. His education was in local schools, but after completion, he worked for a farmer who was somewhat more educated and a member of the school board. One thing led to another, and Burt was made aware of the State Normal School in Albany which offered a course in botany. Burt applied and entered.

In his senior year, Burt was offered a job teaching penmanship, bookkeeping, and English at the Albany Academy, where he taught for five years. He then filled a vacancy back at the State Normal School in 1891, teaching natural history. Serendipitously, he was offered an opportunity to enter Harvard as a sophomore without an entrance examination. There, of course, he came under the influence of Professors William G. Farlow and Roland Thaxter. Burt was awarded a bachelor's degree in 1893 and stayed on for an A.M. in 1894 and Ph.D. in 1895 (at 36 years of age). Although his dissertation was on phalloids, he expressed his intention to work on the *Thelephoraceae*, at that time a large and very variable fungal group.

Burt's time at Harvard was followed by 18 years on faculty at Middlebury College, Vermont. Teaching loads were heavy and diverse—several botany courses, forestry, geology, zoology, comparative anatomy, bacteriology—leaving little time for research. Grading exams, mentoring students, and raising a growing family bit into out-of-class time. Vacations were planned around visits to Harvard (Cryptogamic Herbarium) and Philadelphia (Schweinitz herbarium). He spent one summer in Europe sectioning the type specimens in the larger herbaria and collecting Friesian species in the vicinity of Uppsala, Femsjö, and Stockholm.

In 1912, George T. Moore succeeded William Trelease as Director of the Missouri Botanical Garden and Dean of the Henry Shaw School of Botany at Washington University, St. Louis. Moore led an expansion of

both institutions, and one of the faculty hired was E.A. Burt as librarian and mycologist at the Garden. Burt taught courses but had significantly more time for his research. Moore had already established the Annals of the Missouri Botanical Garden, so Burt had a ready journal in which to publish each part of his monograph. Some 20 years later, Burt finished the *Thelephoraceae* monograph, and suffering from degenerating eyesight, he retired in 1933. His wife died in 1938 and Burt succumbed in 1939.

Initially, Lloyd's judgement of Burt was laudatory. As mentioned above, his praise was tangential (Lloyd 1915d): "I am gratified that Mr. Overholts has gotten back to the realms of rational mycology. I presume that this is due to the conservative influence of Professor Burt [by 1915 on faculty at Washington University]." (See also excerpts from Lowe letter above in Chapter 2.)

Two years later, Lloyd (1917a: p. 652) featured Burt's photo portrait as the cover of one of his Mycological Notes: "We hold Prof. Burt to be one of the few really earnest, scholarly men at work on American mycology. To his specialty, the *Thelephoraceae,* he has given years of careful and close study.

"Fifteen or twenty years ago, Prof. Burt spent a season in Europe, studying such specimens as he collected, or found at Kew or Uppsala. It is to be regretted that he did not go to Leiden, the home of Persoon's specimens, where are to be found the 'real' types of many of these species. I have not much sympathy with the idea, now 'legal,' of starting [mycological nomenclature] with Fries, particularly in the cases where he did not get Persoon's species right, and there are many cases of this kind among the resupinates.

"Prof. Burt has been slow in publishing, and it is only in the last two or three years that we have had much benefit from his studies. We trust that his work will not be interrupted, until finished. In our opinion, the resupinates will never be a very popular study, as long as they involve as much work as at present, sectioning each specimen. We think the study can be made more practical, but that is for the future.

"Prof. Burt and Bresadola are, we believe, the only two conscientious 'priorists' living. This very quality, indeed, has led Bresadola into many illogical conclusions as to the names he uses, and judging from Burt's troubles with '*Septobasidium pedicellatum*,' he will meet the same difficulty.

"Prof. Burt is a very careful, safe, conservative man, thorough scholar, a patient worker, a graduate of the best mycological college in our country (Harvard), and he is working on the most difficult problems existing in connection with American mycology."

MYCOLOGICAL NOTES.

BY C. G. LLOYD.

No. 47.

CINCINNATI, O. APRIL, 1917.

PROFESSOR EDWARD ANGUS BURT.

FIG. 6. Edward Angus Burt.
Lloyd. Mycological Notes No. 47. 1917.

Later that year, however, Lloyd (1917b: 4) began to carp: "Burt has been working for years on thelephoraceous plants. He has done in the main good work on the subject. But he has been slow, slower than a snail man. He has part of his work published and may finish it if he reaches the age of Methuselah. They tell a story on this snail man. He described a new species of snail. One of his friends said he must have met it. Surely he never overtook it."

Over time, Lloyd found more reasons to chide: "Recently one of Prof. Burt's students found in our museum a species of *Hydnangium* from Japan, which he published and referred to *Rhizopogon violaceus*. It has no more resemblance to [*Rhizopogon*] than a cannon ball has to a blown-out egg shell. If this is the kind of 'Mycology' Prof. Burt teaches he should take up Egyptian hieroglyphics, for from the results of his teaching his student knew about as much of one subject as he did of the other, if this is a sample of it." [Lloyd 1923, p. 1201, under *Gallacea violacea*]

Later in the same note (Lloyd 1923: 1213, under "Pointed comments"): "Of the species that pass current under the fraudulent advertisement 'Berkeley and Curtis' there is not a single type in the Curtis herbarium and never has been and Burt knows it. … Fifty years later Prof. Burt, a graduate of Harvard, not only knowingly aims to perpetuate this ancient fraud, but goes a step further and misrepresents that the types are in the Curtis herbarium. We might have patience with a four-year-old child telling these little fibs but a man, old enough to be a grandfather, ought to have passed that childish stage, and confine himself to the truth." (The story rated a Tso Kay symbol.)

Not a year later, yet another chastisement (Lloyd 1924b: 1260 under Edge of the Tombs, with Tso Kay imprint): "[Burt's] figure [Plate 282 exhibit F) which was published to represent *Clavaria mucida* was not found in the tomb of Tutankhamen, as would naturally appear, but in a recent production of Prof. Burt in his post-Osler days. The art of illustration was a much more advanced state in the days of old King Tut, 3,000 years ago, than Burt is now employing. In order to show how utterly bad it is, we reproduce a good figure (2769) of *Clavaria mucida* from Atkinson. What a pity it is for an old man to issue such work as Burt is now publishing in 'Illustrations' and other matter. After graduating from Harvard, had he taken a post-graduate course in some kindergarten, he could have greatly improved his work in this direction. And such is science, as produced by collegiate graduates." A direct put-down for an 'elite.'

In the very next Mycological Note (Lloyd 1924b: 1312, under *Polyporus sideroides*): "The type is at Leiden (Fig. 3031). It varies at times, having no

stipe, and a specimen of the sessile form was called by Léveillé *Polyporus Korthalsii*. Then Léveillé did not help the matter when he went back to Paris and labeled a specimen of *Fomes senex*, which has no suggestion whatsoever, as being his *Polyporus Korthalsii*. Recently Burt, who knows about as much about foreign *Polyporus* as Léveillé did, and who knows absolutely nothing about this particular case, recently published *Fomes senex* as "*Fomes*" *Korthalsii* (sic) and assumes to pass on questions which he has, and never had, any way of knowing anything at all about. This kind of work is only a bluff and Burt ought to be ashamed of it, and such "work" does not advance "knowledge" one iota and only makes a mess."

Lloyd died in 1926; Burt lived until 1939.

Chapter 6. What's the point?

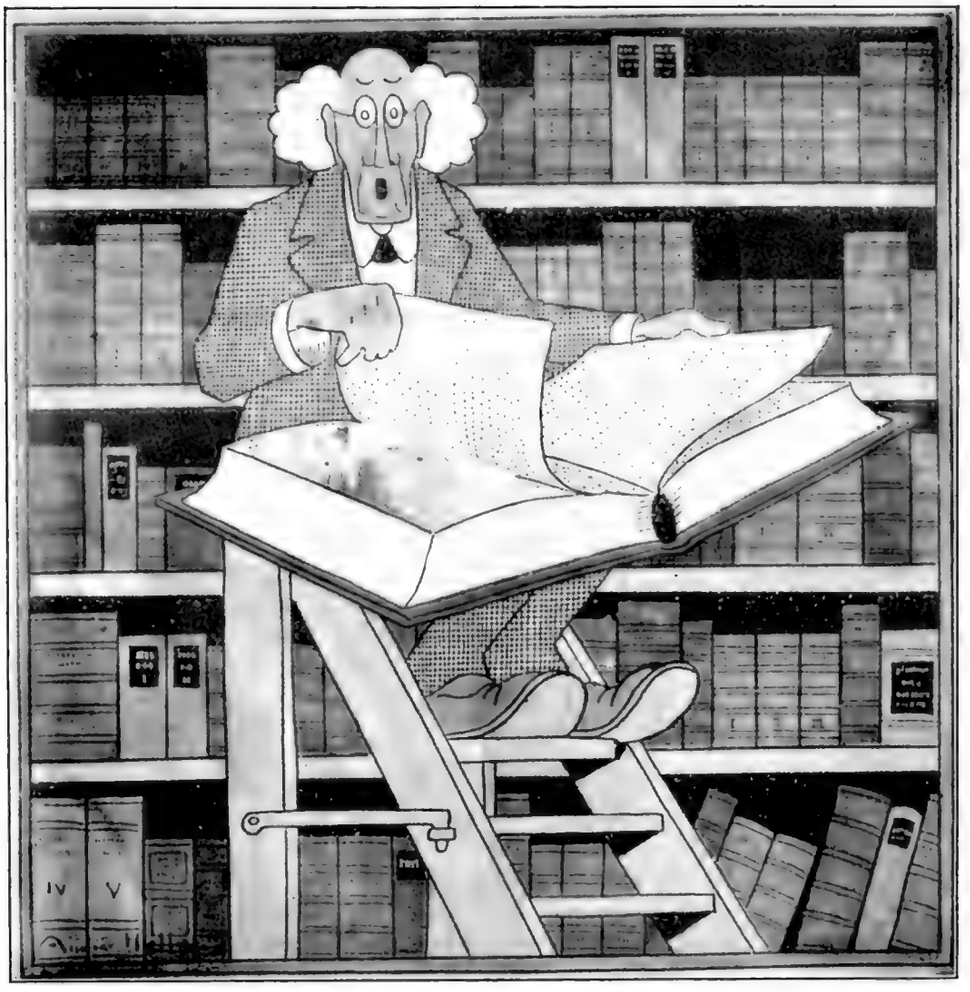
Reviewers, editors and journal ethics. Acquaintance with scientific organizations from the 17–19th centuries reveals fraternal groups. The election of new members, the "reading" of research results to societal conclaves in rooms serving as the society's home, publication of printed summaries of these results were all performed within groups of like-minded men. The Linnaean Societies (at least in England and Sweden) and the French and Russian Academies of Sciences testify to this idea. The inclusion of "Acts of ..." or "Proceedings of..." indicate papers read to a membership meeting and published together with other business performed at the meeting. The increase of scientists engaged in narrower subdisciplines led, for example, to segregate divisions within the American Association for the Advancement of Science (AAAS, with Science as its journal) followed by formation of journals favoring these subdisciplines. The American Journal of Botany, Phytopathology, and Journal of Mycology were examples. A few years later came the Journal of Plant Physiology. Moreover, the readership, whether academic or lay, represented a much more egalitarian group, often of agrarian background. Initial editors were usually leaders of the vocal group lobbying for the journal itself. In Journal of Mycology, although there were three founders, W.A. Kellerman controlled what appeared on its pages, from papers by authors not involved with the machinations of the journal itself to "mycological news" at the end of most issues. William A. Murrill served in the same role for some years with Mycologia. The same applies for John Merle Coulter and Botanical Gazette. The fate of the journals, however, depended on the subscribers; without them, slow starvation was assured.

On the face of it, Lloyd's self-supported mycological publications were incongruous. The major differences were both financial and ethical. Journal of Mycology, for example, although surely supplemented by Kellerman, was dependent on subscribers for its financial existence, while Lloyd was not hampered by such trivialities. The cost of subscription was only the cost of postage to send specimens to Lloyd. Ethically, scientific journals were self-limited to reports of scientific results, with 'news' always positive and tepid; Lloyd was not corralled in this way. That he used his freedom to deride others was a unique idiosyncrasy.

Our current modus operandi of strenuous pre-publication reviews, much rewriting, long lists of co-authors and considerable 'in-press' time is a 20th century phenomenon. Anonymous reviews aim to ensure that the undergirding science and conclusions are valid.

The sowing of seeds. Lloyd's printed publications were only one facet of his persona. Careful readings of his writings show that he travelled widely and often. He mentions Washington (DC), New York, Ellis's home in New Jersey, Morgan's farm in Ohio and other domestic destinations (I don't remember any mention of Harvard in Cambridge, Mass.). Internationally, aside from his very early trip to Samoa, his travel was to Europe. After all, the great herbaria of Europe were homes for classic collections on which species were based, as well as collections from the colonies in Africa, Asia, and other far-off climes. European destinations included Kew and British Museum, the herbarium at the Caroline University in Upsala and the national museum in Stockholm, the royal botanic gardens herbarium in Paris, the national museum in Berlin, universities in Italy and other less stellar locations. Everywhere he went he met, conversed with, used and befriended workers. Everywhere he went those workers took his measure, surely shared their opinions with co-workers and reached conclusions about American mycology as represented by Lloyd. In the same period as Lloyd's European travel, other American mycologists, at least Farlow, Thaxter, Kellerman, Atkinson, Coker, Arthur, Shear, Burt, and others also visited the same destinations, but took no opportunity to describe or lampoon their hosts. The letter from Lowe referenced above, however, paints a very different picture of Lloyd than that implied by his writings. It was surely Lloyd's intimidating pen that led Donk (and Lowe) to find Lloyd guilty of stunting American mycology for a half-century.

That Lloyd's writings were interesting to an audience outside the US can be seen by the geographic origins of specimens he acknowledged publicly. A microcosmic example, though, can be reported thanks to Dr. Shaun Pennycook



Professor McGinty discovering the genus Anthropomorphus.

The picture is a copy of an oil painting that hangs in the rooms of the Poseyville Fungus Forage Club, and shows the Professor in the act of making his momentous discovery.

Fig. 7. Prof. N.J. McGinty.
Lloyd. Letter No. 48. 1913.

(pers. comm.). Dr. Gordon Herriot Cunningham (1892–1962), New Zealand's first resident taxonomic mycologist (Ramsbottom 1964; McKenzie 2004), received Lloyd's publications. He scribbled notes in the margins which, in the case of Lloyd, were often not complimentary. Pennycook (pers. comm.) offered just a few of these jottings, such as "Confused argument of a half-baked crank" (on Lloyd's p. 1341). When Lloyd criticized someone, Cunningham cracked "Exactly the same can be said of the famous Lloyd!" (p. 1267), or "What about your phalloid eggs named as Hysterangiums, Mr. Lloyd!" (p. 1288). So, someone was paying attention a half-world away from Cincinnati.

Lloyd, himself, has come under scrutiny over time. For example, Donk (1951: 205) took Lloyd to task as follows: "C.G. Lloyd coined and published

several names in a jocular spirit. Thus, in his 'Mycological Writings,' fictitious Prof. McGinty acted as the author of a number of new names … Lloyd's intention was to ridicule and imitate certain mycologists he named as 'name jugglers,' 'splitters,' and 'new species hunters.' One point emerges incontestably: the McGinty names were not acceptable to Lloyd himself, the publishing author. However, he repeatedly admonished future authors not to forget the existence of the McGinty names, which he apparently considered validly published. This is clear: these names belong to the class of nomina provisoria! not being accepted by the publishing author, they were 'merely proposed in anticipation of the future acceptance of the group concerned, or of a particular circumscription, position, or rank of the group,' [quote from the governing International Code of Botanical Nomenclature] and hence were not validly published. Many of the McGinty names were often purposely and somewhat maliciously coined after bad examples and served as punishment in store for those who dared to deviate from the usually rather crude taxonomical views to which Lloyd adhered. A number of the names in question were published as nomina nuda. Some were taken up by subsequent authors and validly published on such an occasion."

The denigration of elites. Lloyd was mycologically (at least) self-educated. His stated mentor was Andrew P. Morgan, also mycologically self-educated. In fact, there is no evidence that Lloyd was formally educated past local-school level. In such circumstances, some individuals would be supplicants of the elites of their field of interest. Instead, Lloyd, usually within the bounds of his own myopia, seemed to gloat at his perceived superiority over the credentialed workers. This is most clearly seen in his needling of Edward A. Burt, a triple-degree recipient from Harvard, termed by Lloyd as "the best college in the country." While such belittling was amusing to some readers (and probably mystifying to foreigners), it was unnecessary to make the point.

Cookie-cutter biographies. A close look at the biographies of mycologists and plant pathologists of the late 19th and first half of the 20th century (Hesler 1975, Petersen 2019) reveals a least common denominator of rural, agricultural origins. Again and again we find farm boys. [Remember, history of that era reveals very few women gaining educational credentials or university faculty positions, not terribly surprising given that national women's suffrage was gained only toward the end of the period covered, 1920]. Thus, professional botanists were often farm boys who had become fascinated with the natural world about them. Within this "theorem" there seems to have been at least

two "corollaries." First, the attraction of natural history led to naming: what were the names of the organisms confronted, how were they grouped and what traits required observation to arrive at names, altogether more fastidiously known as taxonomy. The second "corollary:" from a large roster of candidates, it was a sign of the times that the farm boys we recognize were "discovered" by someone of authority. It could be a teacher, it could be a family relative, a neighbor, but someone who could recognize talents and encourage a path to further education. The knack of further selection and mentoring sometimes befell college professors (Petersen 2021).

Today's educational and scientific world has reached a significant level of equality of opportunity. Any meeting of a scientific society testifies that females are not only demographically common but are considered at least as promising as males. Entrance requirements for college, while often daunting, have been "flattened:" SAT scores, scholarships extended to less-wealthy families, and demographic distribution are all aimed at levelling the playing field. Several momentous punctuations can be identified in the "progress" from the period narrated above and the present: The Great Depression, two World Wars, the "GI Bill of Rights," Sputnik, the rise of feminism, "Affirmative Action," "Black Lives Matter" and others. Numerous Ph.D. dissertations have surely been (and surely will be) written on this societal evolutionary process.

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Callosus wenshanensis gen. & sp. nov. from China

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Abstract—A new genus of corticoid wood-inhabiting fungus, *Callosus*, typified by *C. wenshanensis*, is proposed here based on morphological and molecular characters. The species is characterized by resupinate basidiomata with smooth, cream-colored hymenial surfaces, a monomitic hyphal system with generative hyphae bearing simple septa, and basidiospores (2.3–3.9 × 1.4–2.3 µm) that are ellipsoid, hyaline, thin-walled, and smooth. The nrDNA internal transcribed spacer (ITS) and large subunit (28s) sequences were analyzed using maximum likelihood, maximum parsimony, and Bayesian inference methods. Phylogenetic analysis supported *Callosus* in a monophyletic lineage closely related to *Phanerochaete* and *Rhizochaete*.

Key words— *Phanerochaetaceae*, *Polyporales*, taxonomy, Yunnan Province

Introduction

Phanerochaetaceae Jülich (*Polyporales*, *Basidiomycota*) is a diverse family of fungi that grow on boreal, temperate, subtropical, and tropical vegetation (Dai 2012, Dai & al. 2015). The family is characterized by a monomitic hyphal system, generative hyphae without clamp-connections, and thin-walled smooth colorless basidiospores. Its species often possess cystidia and

cause white rot (Justo & al. 2017). Kirk & al. (2008) included 19 genera (+ 9 synonyms) in *Phanerochaetaceae*, but after phylogenetic analyses, Justo & al. (2017) cited 12 genera (+ one synonym), noting that "generic concepts in the family are in need of additional research." Several molecular studies involving the *Phanerochaetaceae* have been conducted (Larsson 2007, Binder & al. 2013, Floudas & Hibbett 2015, Justo & al. 2017).

During a survey of wood-inhabiting fungi in southern China, some interesting collections were encountered that appeared to belong in *Phanerochaetaceae*. ITS and 28S sequence analyses supported these specimens as representing a new genus and species, proposed here as *Callosus wenshanensis*.

Materials & methods

The specimens included in the present study were deposited at the herbarium of Southwest Forestry University, Kunming, Yunnan Province, China (SWFC). Macromorphological descriptions were based on field notes. Color terms follow Petersen (1996). Micromorphological data were obtained from the dried specimens and observed under a Nikon light microscope. The following abbreviations are used: KOH = 5% aqueous potassium hydroxide (w/v), CB = Cotton Blue, CB– = acyanophilous, IKI = Melzer's reagent, IKI– = both non-amyloid and non-dextrinoid, L = mean spore length (arithmetic average of all basidiospores), W = mean spore width (arithmetic average of all basidiospores), Q = variation in the L/W ratios, n = number of spores measured/number of specimens.

Genomic DNA was obtained from dried specimens using the CTAB rapid plant genome extraction kit-DN14 (Aidlab Biotechnologies Co., Ltd) according to the manufacturer's instructions. ITS sequences were amplified using primers ITS5 and ITS4 (White & al. 1990) and 28S sequences using primers LR0R and LR7 (https://sites.duke.edu/vilgalyslab/rdna_primers_for_fungi/). The ITS was amplified as follows: initial denaturation at 95 °C for 3 min, followed by 35 cycles at 94 °C for 40 s, 58 °C for 45 s and 72 °C for 1 min, and a final extension of 72 °C for 10 min. The 28S region was amplified as follows: initial denaturation at 94 °C for 1 min followed by 35 cycles at 94 °C for 30 s, 48 °C for 1 min, and 72 °C for 1.5 min and a final extension of 72 °C for 10 min. The PCR amplicons were purified and directly sequenced by Kunming Tsingke Biological Technology Ltd. Co.

The resulting DNA sequences were deposited in GenBank (Table 1) and edited using Sequencher 4.6 (Gene Codes). The sequences were aligned using the "G-INS-i" strategy in MAFFT 7 (http://mafft.cbrc.jp/alignment/server/) and then manually adjusted in BioEdit (Hall 1999). The sequence alignment was deposited in TreeBase (Submission ID 27178). For phylogenetic analysis, sequences of *Candelabrochaete africana* Boidin were obtained from GenBank for use as outgroup (Fig. 1) following Floudas & Hibbett (2015). *Bjerkandera adusta* (Willd.) P. Karst. and *Ceriporiopsis carnegieae* (D.V. Baxter) Gilb. & Ryvarden were obtained for use as outgroup taxa (Fig. 2) following Justo & al. (2017).

Table 1. Species, specimens, and sequences used in this study. New sequences in **bold**.

Species	Voucher	GenBank accession no.		Reference
		ITS	nLSU	
Bjerkandera adusta	HHB 12826	KP134983	KP135198	Justo & al. 2017
Callosus wenshanensis	**CLZhao 16017 T**	**MW553934**	**MW553936**	This study
	CLZhao 16034	**MW553935**	**MW553937**	This study
Candelabrochaete africana	FP 102987	KP135294	KP135199	Floudas & Hibbett 2015
Ceriporia purpurea	KKN-223	KP135044	KP135203	Floudas & Hibbett 2015
C. reticulata	RLG-11354	KP135041	KP135204	Floudas & Hibbett 2015
C. viridans	Yuan 5702	KC182779	—	Floudas & Hibbett 2015
Ceriporiopsis carnegieae	RLG-7277	KY948792	KY948854	Justo & al. 2017
Efibula americana	FP-102165	KP135016	KP135256	Floudas & Hibbett 2015
E. clarkii	FD-228	KP135019	—	Floudas & Hibbett 2015
E. gracilis	FD-455	KP135027	—	Floudas & Hibbett 2015
Hydnophlebia chrysorhiza	FD-282	KP135338	KP135217	Floudas & Hibbett 2015
H. omnivora	KKN-112	KP135334	KP135216	Floudas & Hibbett 2015
Phaeophlebiopsis caribbeana	HHB-6990	KP135415	KP135243	Floudas & Hibbett 2015
P. peniophoroides	FP-150577	KP135417	KP135273	Floudas & Hibbett 2015
Phanerochaete alnea	Larsson 12054	KX538924	—	Floudas & Hibbett 2015
P. arizonica	RLG-10248	KP135170	KP135239	Justo & al. 2017
P. australis	HHB-7105	KP135081	KP135240	Floudas & Hibbett 2015

Species	Voucher	GenBank accession no.		Reference
		ITS	nLSU	
P. chrysosporium	HHB-6251	KP135094	KP135246	Justo & al. 2017
P. ericina	HHB-2288	KP135167	KP135247	Justo & al. 2017
P. magnoliae	HHB-9829	KP135089	KP135237	Justo & al. 2017
P. pseudomagnoliae	PP-25	KP135091	KP135250	Justo & al. 2017
*P. rhodell*a	FD-18	KP135187	KP135258	Justo & al. 2017
P. sordida	FD-106	KP135070	KP135253	Floudas & Hibbett 2015
P. subceracea	FP-105974	KP135162	KP135255	Justo & al. 2017
*Phlebia acerin*a	FD-301	KP135378	KP135260	Floudas & Hibbett 2015
P. floridensis	HHB-9905	KP135383	KP135264	Floudas & Hibbett 2015
P. radiata	AFTOL-484	AY854087	AF287885	Floudas & Hibbett 2015
Phlebiopsis crassa	KKN-86	KP135394	KP135215	Greslebin & al. 2004
P. galochroa	FP-102937	KP135391	KP135270	Justo & al. 2017
P. gigantea	FP-70857	KP135390	KP135272	Greslebin & al. 2004
Rhizochaete brunnea	MR-229	AY219389	AY219395	Greslebin & al. 2004
R. filamentosa	HHB-3169	KP135410	KP135278	Justo & al. 2017
R. fouquieriae	KKN-121	AY219390	AY219390	Floudas & Hibbett 2015
R. radicata	FD-123	KP135407	KP135279	Justo & al. 2017
Scopuloides hydnoides	KHL-11916	EU118665	—	Floudas & Hibbett 2015
S. rimosa	RLG-5104	KP135351	KP135283	Floudas & Hibbett 2015

Maximum parsimony analysis was performed using PAUP* version 4.0b10 (Swofford 2002). All characters were equally weighted, and gaps were treated as missing data. Trees were inferred using the heuristic search option with TBR branch swapping and 1000 random sequence additions. Max-trees were set to 5000, branches of zero length were collapsed and all parsimonious trees were saved. Clade robustness was assessed using bootstrap (BT) analysis with 1000 replicates (Felsenstein 1985). Descriptive tree statistics, including tree length (TL), consistency index (CI), retention index (RI), rescaled consistency index (RC), and homoplasy index (HI) were calculated for each Maximum Parsimonious Tree (MPT) generated. Maximum Likelihood (ML) phylogenetic analysis was performed using RAxML-HPC2 via the Cipres Science Gateway (www.phylo.org; Miller & al. 2010).

For Bayesian inference (BI), the best-fit evolution model for each dataset was determined using MrModeltest 2.3 (Nylander 2004), and BI was performed in MrBayes 3.1.2 (Ronquist & Huelsenbeck 2003), using a general time reversible (GTR+I+G) model of DNA substitution and a gamma distribution for across-site rate variation. Four Markov chains were run for 2 runs from random starting trees for 900,000 for the ITS+28S dataset (Fig. 1) and for 50,000 for ITS+28S (Fig. 2) and trees were sampled every 100 generations. The first one-fourth generations were discarded as burn-in. A majority rule consensus tree of all remaining trees was calculated. Branches were considered significantly supported if they received BS >70%, BT >50%, or BPP >0.95.

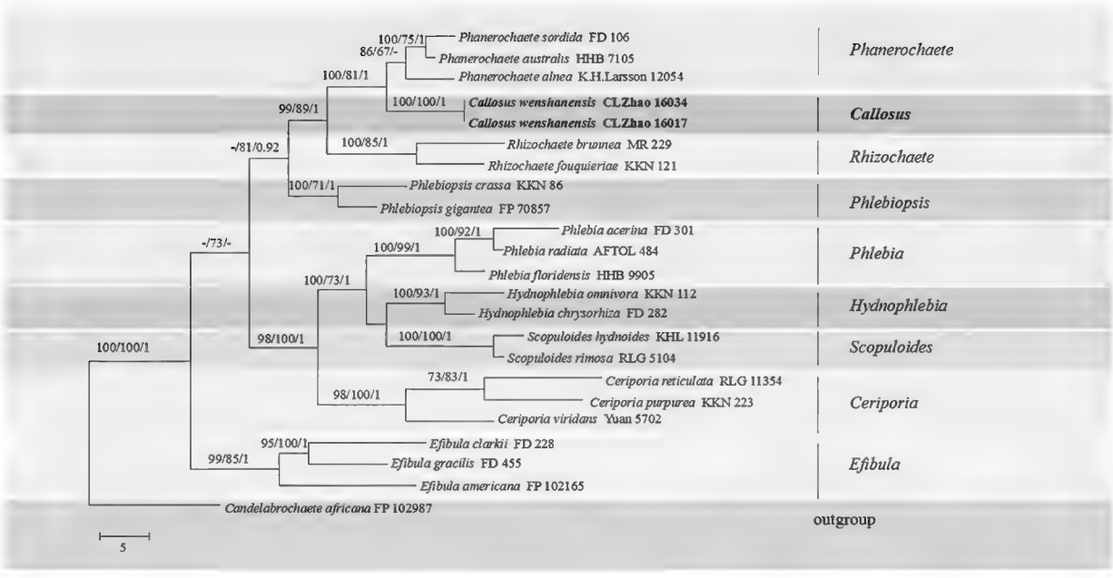

Fig. 1. Maximum parsimony strict consensus tree illustrating the phylogeny of *Callosus wenshanensis* and related genera in *Phanerochaetaceae* based on ITS+nLSU sequences. Generic names follow Floudas & Hibbett (2015). Branches are labelled with maximum likelihood bootstrap value >70%, parsimony bootstrap value >70% and Bayesian posterior probabilities >0.95.

Phylogenetic results

The 22 concatenated ITS+28S sequences used for phylogenetic analyses included sequences from representatives of *Efibula* Sheng H. Wu, *Ceriporia* Donk, *Hydnophlebia* Parmasto, *Phanerochaete* P. Karst., *Phlebiopsis* Jülich, *Phlebia* Fr., *Rhizochaete* Gresl. & al., and *Scopuloides* (Massee) Höhn. & Litsch. (Fig. 1)

The sequence alignment was 2260 bp long, of which 1627 were constant, 209 parsimony-uninformative, and 424 parsimony-informative. The MP analysis yielded two equally most-parsimonious trees (TL = 325, CI = 0.529, HI = 0.471, RI = 0.560, RC = 0.297). The best-fit BI model for the ITS+28S alignment was GTR+I+G [lset nst = 6, rates = invgamma; prset statefreqpr = dirichlet (1,1,1,1)]. The BI and ML analyses yielded topologies similar to those yielded by MP analysis, with an average standard deviation of split frequencies equal to 0.009325.

Regardless of analysis method, the phylogenetic trees inferred from the ITS+28S sequences indicated that the specimens of interest formed a strongly supported monophyletic clade (BS = 100%, BT = 100%, BPP = 1) and were closely related to *Phanerochaete* and *Rhizochaete* (Fig. 1).

The ITS+28S dataset included sequences from 22 fungal specimens representing 21 taxa in *Phanerochaete*, *Phaeophlebiopsis* Floudas & Hibbett, *Phlebiopsis*, and *Rhizochaete* (Fig. 2).

The sequence alignment was 2130 bp long, of which 1680 were constant, 124 parsimony-uninformative, and 326 parsimony-informative. The MP analysis yielded two equally most-parsimonious trees (TL = 786, CI = 0.570, HI = 0.430, RI = 0.645, RC = 0.367). The best-fit BI model for ITS+28S alignment was GTR+I+G [lset nst = 6, rates = invgamma; prset statefreqpr = dirichlet (1,1,1,1)]. The BI and ML analyses yielded topologies that were similar to those yielded by MP analysis, with an average standard deviation of split frequencies equal to 0.008889.

Regardless of analysis method, the phylogenetic trees inferred from the ITS+28S sequences placed the specimens of interest in a strongly supported monophyletic clade (BS = 100%, BT = 100%, BPP = 1) closely related to *Phanerochaete* and *Phaeophlebiopsis* (Fig. 2).

In addition, BLAST results comparing ITS sequences from the Chinese specimens and species in the NCBI database showed a high similarity with *Phanerochaete* sp. (Maximum & total score 749; Query coverage 93%; E value 0; Identity 88.58%) and *P. sordida* (P. Karst.) J. Erikss. & Ryvarden (Maximum & total score 734; Query coverage 87%; E value 0; Identity 89.24%). Those

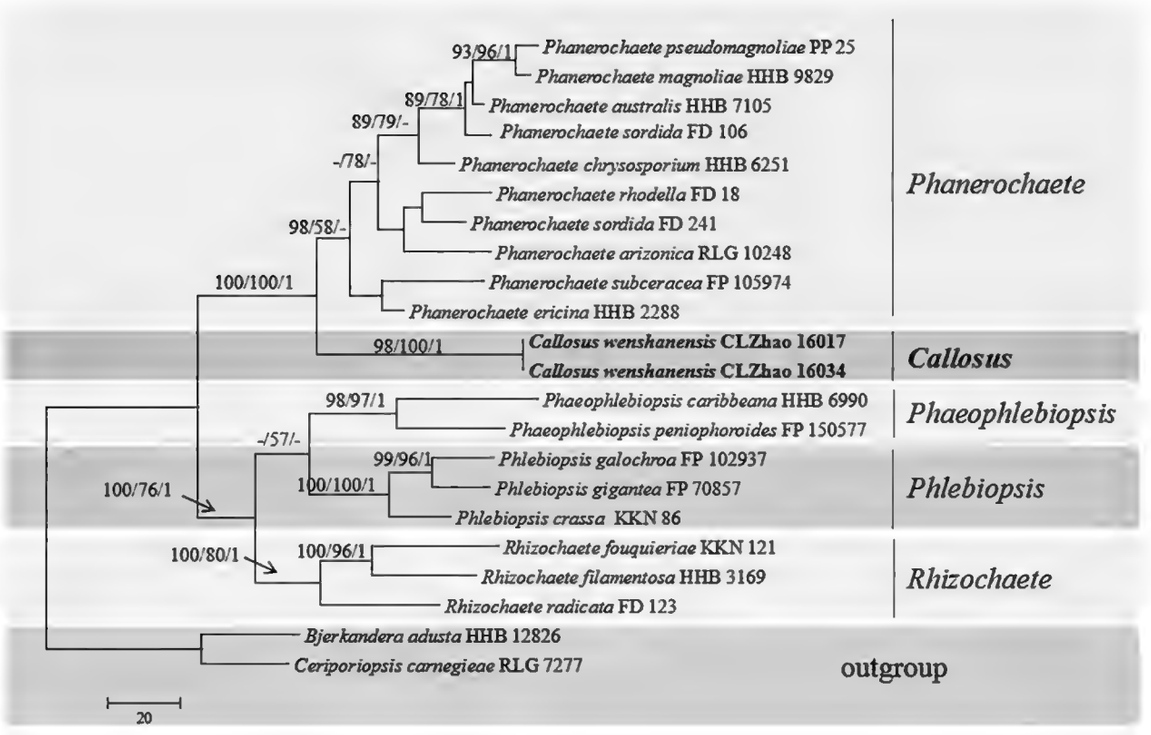

FIG. 2. Maximum parsimony strict consensus tree illustrating the phylogeny of *Callosus wenshanensis* and related species in *Phanerochaetaceae* based on ITS+nLSU sequences. Generic names follow Justo & al. (2017). Branches are labelled with maximum likelihood bootstrap value >70%, parsimony bootstrap value >70% and Bayesian posterior probabilities >0.95.

comparing 28S sequences showed a high similarity with *Phanerochaete* sp. (Maximum & total score: 2412; Query coverage 99%; E value 0; Identity 98.19%) and *P. cystidiata* Sheng H. Wu & al. (Maximum & total scores 2409; Query coverage 98%; E value 0; Identity 98.47%).

Taxonomy

Callosus C.L. Zhao, **gen. nov.**

MB 838558

Differs from *Phanerochaete* by its membranous basidiomata with a lubricative hymenial surface and the presence of crystals between subhymenium and subiculum.

TYPE SPECIES: *Callosus wenshanensis* C.L. Zhao

ETYMOLOGY: *Callosus* (Lat.) refers to the hard membranous basidioma and its smooth hymenophore.

BASIDIOMATA annual, resupinate, membranous. Hymenial surface smooth, white to cream. Hyphal system monomitic; generative hyphae bearing simple septa, IKI–, CB–; tissues unchanged in KOH. Cystidia capitate, cystidioles

absent. Basidia clavate to cylindrical, with four sterigmata. Basidiospores ellipsoid, colorless, thin-walled, smooth, IKI–, CB–.

Type of rot: white rot.

Callosus wenshanensis C.L. Zhao, **sp. nov.** Figs 2, 3

MB 838559

Differs from *Phanerochaete alnea* by its white to cream-colored basidiomata and smaller basidiospores.

Type: China. Yunnan Province, Wenshan, Baxin Town, Wenshan National Nature Reserve, on fallen angiosperm branch, 24 July 2019, C.L. Zhao 16017 (**Holotype**, SWFC 0016017; GenBank MW553934, MW553936).

Etymology: *wenshanensis* (Lat.) refers to the provenance of the specimens.

Basidiomata annual, resupinate, membranous, without odor or taste when fresh, becoming hard membranous and fragile upon drying, ≤10 cm long, 2.5 cm wide, 1 mm thick. Hymenial surface smooth, white to cream-colored when fresh, becoming cream-colored and cracking upon drying. Margin sterile, narrow, 1 mm wide, white to cream.

Hyphal structure monomitic; generative hyphae with simple septa, colorless, thin- to thick-walled, unbranched, 1.5–2.3 μm in diameter, IKI–, CB–; tissues unchanged in KOH.

Subiculum subhymenium and subiculum distinct, subicular hyphae loosely arranged, subhymenium covered with crystals.

Hymenium cystidia capitate, colorless, thin-walled, progressively broader towards the top, 23.5–27.2 × 3.2–3.7 μm. Basidia clavate to cylindrical, with four sterigmata, 16.2–17.1 × 2.7–3.4 μm, basidioles dominant, similar in shape to basidia, but slightly smaller.

Basidiospores ellipsoid, colorless, thin-walled, smooth, with 1–2 bubbles, IKI–, CB–, 2.3–3.9 (–4.1) × 1.4–2.3 μm, L = 3.02 μm, W = 1.73 μm, Q = 1.68–1.82 (n = 60/2).

Type of rot: white rot

Additional specimen examined: **CHINA. Yunnan province. Wenshan**: Baxin town, Wenshan National Nature Reserve, on fallen angiosperm branch, 24 July 2019, C.L. Zhao 16034 (SWFC 0016034; GenBank MW553935, MW553937).

Discussion

The proposed new genus, *Callosus*, is supported based on both phylogenetic analyses and morphological characters.

Floudas & Hibbett (2015) revised the taxonomy of *Phanerochaete* (*Polyporales*, *Basidiomycota*) using four nuclear ribosomal gene markers (RPB1,

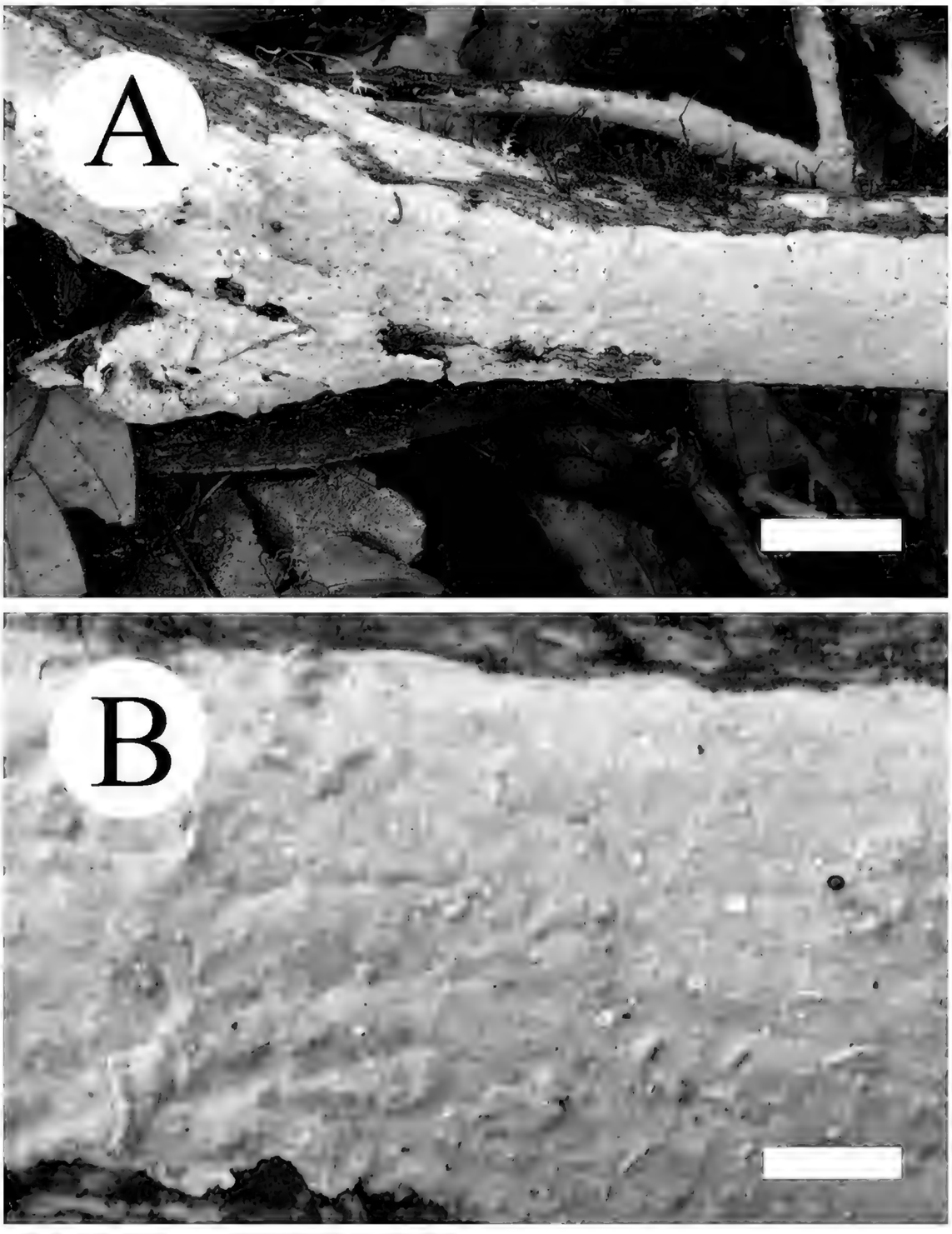

Fig. 3. *Callosus wenshanensis* (holotype, SWFC 0016017).
A. Habit; B. Characteristic hymenophore. Scale bars: A = 1 cm; B = 0.5 cm.

RPB2, ITS and 28S), in which *Hydnophlebia*, *Phaeophlebiopsis*, *Phanerochaete*, *Phlebia*, *Phlebiopsis*, *Rhizochaete*, and *Scopuloides* grouped together within the residual polyporoid clade. The present study found that ITS+28S sequences

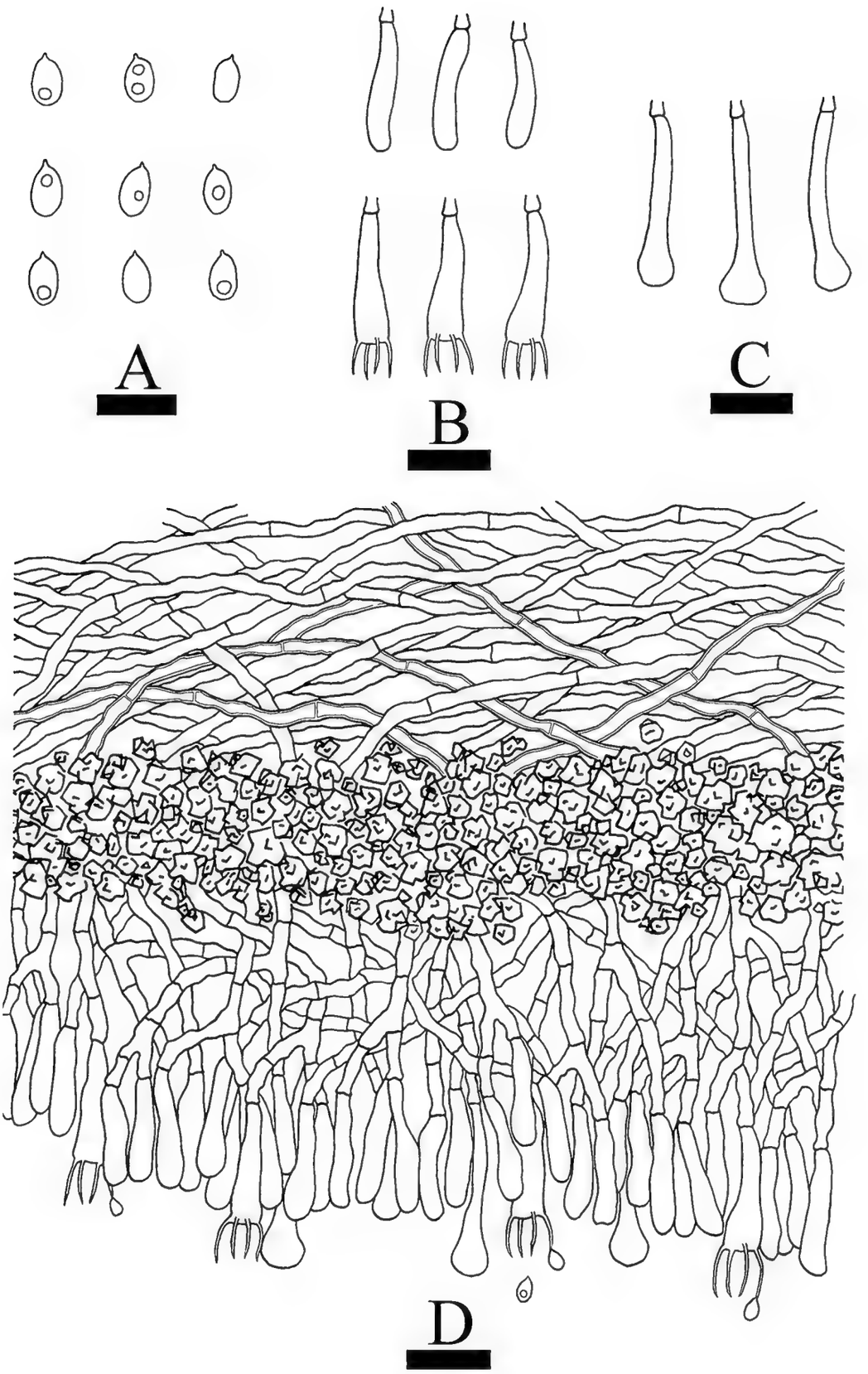

Fig. 4. *Callosus wenshanensis* (holotype, SWFC 0016017).
A. Basidiospores; B. Basidia and basidioles; C. Cystidia; D. Section of hymenium.
Scale bars: A = 5 μm, B–D = 10 μm.

from *Callosus wenshanensis* form a strongly supported monophyletic lineage closely related to *Phanerochaete* and *Rhizochaete* (Figs 1 & 2). However, *C. wenshanensis* differs morphologically from *P. alnea* (Fr.) P. Karst., which is distinguished by its pale pink to pale ochraceous basidiomata, basidioma with fibrillose margin, short hyphal strands, and larger basidiospores (4.9–7.5 × 2.9–4 µm, Spirin & al. 2017), and from *Rhizochaete brunnea* Gresl. & al., distinguished by tuberculate hymenial surfaces, tissues that turn violet in KOH, brown cystidia, clamped generative hyphae, and larger basidiospores (5–6.5 × 3–3.5 µm, Greslebin & al. 2004). A morphological comparison between *Callosus* and related genera is presented in Table 2.

Corticoid fungi are extensively studied and well-known worldwide (Bernicchia & Gorjón 2010; Dai 2012; Dai & al. 2015), but Chinese corticoid fungi diversity is still being explored, especially in subtropical and tropical areas. *Callosus wenshanensis* is from Yunnan Province, where many new taxa in *Phanerochaetaceae* have been described (Wu & al 2010; Zhao & Ma 2019; Ma & Zhao 2019 Ma & al. 2020; Xu & al. 2020). We anticipate that additional, undescribed corticoid fungi will be discovered throughout China after extensive collection combined with morphological and molecular analyses.

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Special thanks are due to Drs. Shah Hussain (Center for Plant Sciences and Biodiversity, University of Swat, Pakistan) and Lu-Sen Bian (Experiment Center of Forestry in North China, Chinese Academy of Forestry, P.R. China) for expert presubmission review. The research was supported by the National Natural Science Foundation of China (Project No. 32170004), Yunnan Fundamental Research Project (Grant No. 202001AS070043), the High-level Talents Program of Yunnan Province (YNQRQNRC-2018-111).

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Table 2. A morphological comparison of *Callosus* with closely related genera.

Genus	Fruitbody	Hymenophore	Clamp connections	Hyphal system	Cystidia	Subiculum	Reference
Callosus	Resupinate, adnate, and hard	Smooth	Absent	Monomitic	Capitate	Loosely arranged, covered with crystals	This study
Efibula	Resupinate	Smooth	Absent	Monomitic	Absent	Compact	Wu 1990
Hydnophlebia	Resupinate	Odontioid	Rare	Monomitic	Leptocystidia	Well-developed, loose	Parmasto 1967
Phaeophlebiopsis	Resupinate, and hard	Smooth	Rare or absent	Monomitic	Subulate or capitate	Well-developed, loose	Floudas & Hibbett 2015
Phanerochaete	Resupinate to slightly reflexed	Smooth, tuberculate or odontioid	Rare or absent	Monomitic	Present	Well-developed, loose	Karsten 1889
Phlebiopsis	Resupinate	Smooth to tuberculate	Absent	Monomitic	Metuloids	Compact	Jülich 1978
Rhizochaete	Resupinate	Smooth or slightly tuberculate	Absent, occasional, or present	Monomitic	Mostly present	Well-developed, loose	Greslebin & al. 2004
Scopuloides	Resupinate	Odontioid	Absent	Monomitic	Metuloids	Almost absent, compact	Burdsall 1985

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Tilletia dichelachnes sp. nov. from New Zealand

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Abstract—A new species of smut fungus, *Tilletia dichelachnes*, is described from New Zealand. The teliospores of this species are very large and comparable in size to only four other species of *Tilletia*. *Tilletia dichelachnes* infects the flowers of an indigenous grass, *Dichelachne crinita* and is the first *Tilletia* species known on the genus.

Key words—bunt, covered smut, large spore, native fungus

Introduction

Some specimens of fungi were recently received from the University of Canterbury, most of which were collected by R.F. Ross McNabb (Thomson 1973) in the South Island of New Zealand in the 1960s. Among them was a smut fungus parasitising the ovaries of the native long-hair plume grass *Dichelachne crinita* (L. f.) Hook. f. (*Poaceae*). Morphologically it differs from other *Tilletia* species recorded in New Zealand by its large teliospores. Smut fungi are basidiomycetous microfungi that grow as biotrophic plant parasites both within and between plant cells.

Materials & methods

A dried herbarium specimen of a smutted grass was received from University of Canterbury. For light microscopy, teliospores were removed from the specimen, mounted in lactophenol on glass slides, and examined using an Olympus BH-2 microscope. For scanning electron microscopy (SEM), a small amount of dried

infected plant material was placed on sticky carbon tab adhering to a specimen stub. This was teased apart to release the spores and distribute them over the surface of the tab. The sample was then sputter coated with gold for 60 seconds and viewed in a SEM using an accelerating voltage of 10kV. The specimen was deposited in the New Zealand Fungarium, Manaaki Whenua – Landcare Research, Auckland, New Zealand (PDD).

Taxonomy

Tilletia dichelachnes McKenzie, **sp. nov.** FIG. 1

IF 558646

Differs from all other species of *Tilletia* by its large teliospores and host plant genus.

TYPE: New Zealand, Mid Canterbury, Torlesse Range, 1 March 1964, on *Dichelachne crinita*, R.F.R. McNabb no. 68 (**Holotype**, PDD 117532).

ETYMOLOGY: From host genus, *Dichelachne.*

SORI concealed and filling caryopsis with a dark reddish brown spore mass, semi-agglutinated to pulverulent. TELIOSPORES 38.5–49 × 35.5–46.5 µm (mean = 44.4 × 42.2 µm, n = 40), globose or subglobose, brown; wall 1–1.5 µm thick, appearing reticulate in light microscope surface view, 8–15 meshes per spore diameter, irregularly warted in scanning electron microscope, warts 2–4 µm high. STERILE CELLS few, subglobose or irregular, 18–25 × 13–21 µm (n = 10), hyaline, wall 1.5–2.75 µm thick, smooth.

Dichelachne crinita [long-hair plume grass or pātītī (New Zealand Māori)] is indigenous to Australasia (Australia, New Zealand, Pacific Islands). It is found throughout New Zealand, usually in open vegetation under light scrub or forest, and in tussock grassland (Edgar & Connor 2010).

Discussion

The sori of *Tilletia* species most commonly form in the ovaries of grasses, producing so-called 'bunt balls.' Of the eleven species of *Tilletia* recorded in New Zealand (McKenzie & Vánky 2001; Vánky & McKenzie 2002), most are widely distributed in the world and have undoubtedly been introduced with seeds or soil. Only two species of *Tilletia* appear to be of Australasian origin. Both were described from Australia but are also known from New Zealand on two native grasses. *Tilletia cathcartae* Durán & G.W. Fisch. was recorded in New Zealand on the endemic *Poa pusilla* Berggr. and *P. xenica* Edgar & Connor (McKenzie & Latch 1984) and *T. inolens* McAlpine on indigenous *Deyeuxia quadriseta* (Labill.) Benth. (Cunningham 1945). The teliospores of *T. dichelachnes* are large in comparison with most other *Tilletia* species in New Zealand. Only three species have similarly large teliospores, but they are still

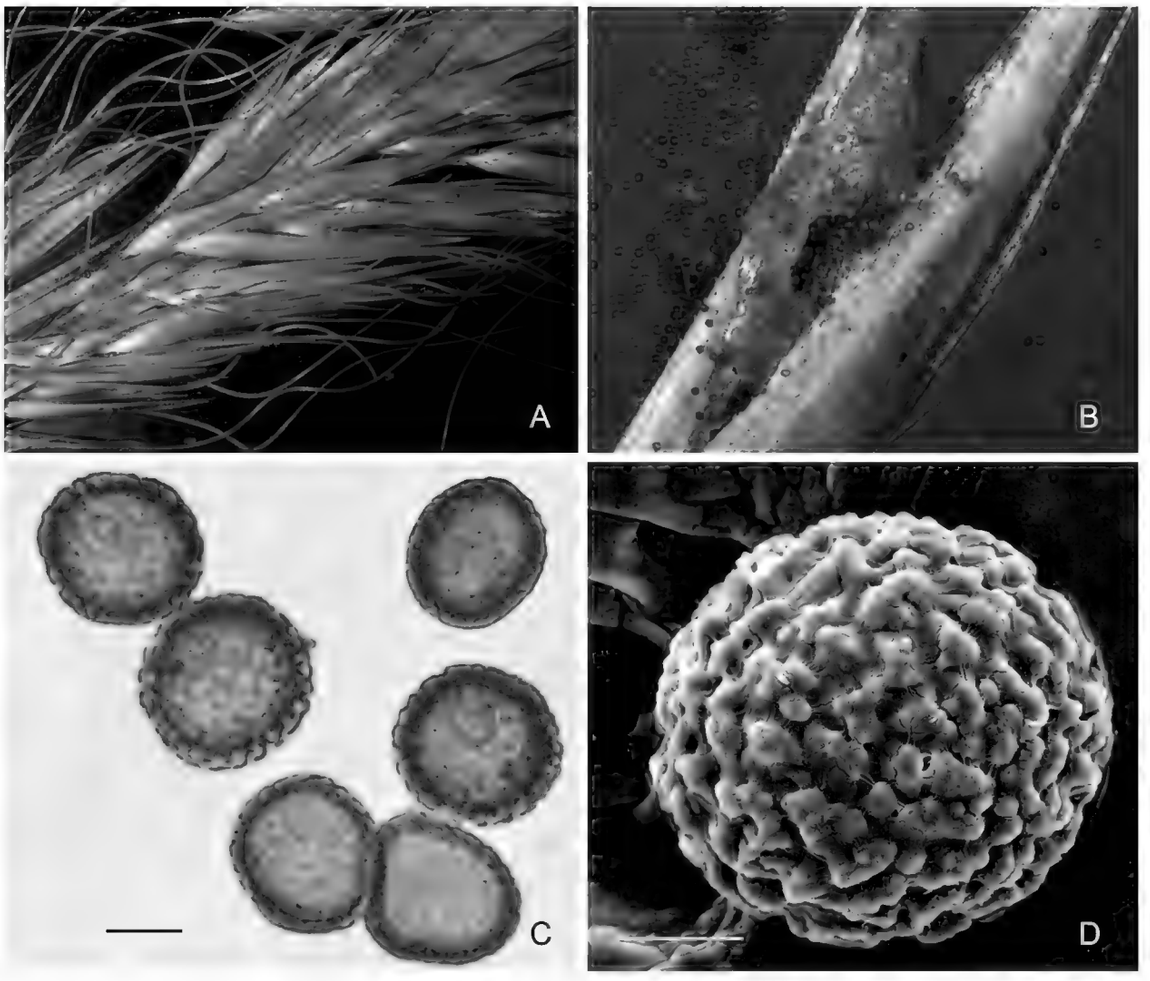

FIG. 1. *Tilletia dichelachnes* (PDD 117532, holotype): A. Smut-infected flowering head of *Dichelachne crinita*; B. Caryopsis broken open to expose teliospores; C. Teliospores by light microscopy; D. Teliospore by scanning electron microscopy. Scale bars: C = 20 µm; D = 10 µm.

smaller than *T. dichelachnes*. Teliospores of *T. cathcartae* are 32–42 × 30–36 µm, *T. inolens* 36–45 × 32–40 µm, and *T. walkeri* Castl. & Carris 24–36(–40) × 23.5–36(–39) µm (Vánky & McKenzie 2002). When observed by scanning electron microscopy, the teliospores of these three species are also covered in warts rather than being reticulate as are some *Tilletia* species (Vánky 2012).

Of the worldwide known species of *Tilletia* described by Vánky (2012) only four have teliospores as large as those of *T. dichelachnes*. These are *T. eragrostiellae* Vánky & al. (36–52 × 40–60(–65) µm, on *Eragrostiella* spp., South Asia), *T. paradoxa* Jacz. (42–47 × 44–50 µm, on *Phleum* sp., Georgia), *T. puneana* Vánky (28–48 × 32–50 µm, on *Polytoca* sp. and *Chionachne* spp., India), and *T. transiliensis* M.N. Kusnezowa & Schwarzman (31–44(–46) × 34–48(–50) µm, on *Poa* sp., Eurasia). *Dichelachne*, *Phleum*, and *Poa* are in

the grass subfamily *Pooideae*, *Eragrostiella* is in subfamily *Chloridoideae*, and *Chionachne* and *Polytoca* are in subfamily *Panicoideae* (Soreng & al. 2015). The teliospores of *T. paradoxa* have spines that are 4–7 µm long while *T. transiliensis* has similar spines that are 3–6.5 µm long (Vánky 2012), making them distinct from those of *T. dichelachnes*. *Tilletia eragrostiellae* is distinct because of its 4–8(–9) µm high warts on the teliospores while *T. puneana* has dense 3–6.5 µm long, thin warts (Vánky 2012).

There appear to be no other records of *Tilletia* occurring on a species of *Dichelachne* (Vánky 2012; Farr & Rossman 2022), but another smut, *Tranzscheliella hypodytes* (Schltdl.) Vánky & McKenzie has been recorded on *D. crinita* in Australia (Cook & Dubé 1989; Vánky & Shivas 2008) and on *Dichelachne* sp. in India (Gandhe 2011). In New Zealand, the cosmopolitan *T. hypodytes* is found on *Austrostipa nodosa* (S.T. Blake) S.W.L. Jacobs & J. Everett, *Elymus rectisetus* (Nees) Á. Löve & Connor [= *Anthosachne rectiseta* Barkworth & S.W.L. Jacobs], *Elytrigia repens* (L.) Nevski [≡ *Elymus repens* (L.) Gould], and *Poa cita* Edgar (Vánky & McKenzie 2002). However, this fungus produces blackish brown sori in the culms.

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Dictyocheirospora himachalensis sp. nov. from Himachal Pradesh, India

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Abstract—A new species of sporodochial fungus, *Dictyocheirospora himachalensis*, characterized by cylindrical-ellipsoidal, pale olivaceous-brown conidia composed of seven non-complanate rows of cells, is described and illustrated. A comparative table of *Dictyocheirospora* species is provided.

Key words—appendages, *Dictyosporiaceae, Pleosporales,* asexual fungi, subtropical

Introduction

India is one of the richest reservoirs of the mycological diversity in Asia. In recent years many wood-inhabiting macrofungi and hyphomycetes have been first discovered in India (Adamčik & al. 2015; Buyck & al. 2017; Prasher & Verma 2014, 2015a,b,c, 2016; Rajeshkumar & al. 2018, 2021; Sushma & al. 2020; Verma & al. 2019, 2021a,b,c,d). Himachal Pradesh, located in

Northwestern India, ranges in altitude from 350–6975 m a.s.l. Its average rainfall of 907–1242 mm year favors an inestimable wealth of macro- and microfungi.

During a survey of microfungi in Mandi district (subtropical monsoon, mild and dry winter, hot summer) of Himachal Pradesh, an interesting fungus was collected from bark of *Eucalyptus* species. Critical morphological examination and comparison revealed the specimen to represent an undescribed species of *Dictyocheirospora* (Boonmee & al. 2016; Wang & al. 2016; Hyde & al. 2017, 2019; Tibpromma & al. 2018; Yang & al. 2018; Jayasiri & al. 2019; Phookamsak & al. 2019; Phukhamsakda & al. 2020). The fungus is proposed as a new species, *Dictyocheirospora himachalensis*, and described and illustrated. A synopsis of the morphological characters of the 23 *Dictyocheirospora* species is included.

Materials & methods

Decaying twigs, decayed wood, and bark were collected into separate Ziplock plastic bags and taken to the laboratory. For light microscopy examination, the specimens were mounted on glass slides in 4% KOH or lactophenol cotton blue (0.01% cotton blue in lactophenol). The specimens were studied under Vevor stereo trinocular VL–Z60 and VRS–2f compound microscopes for macroscopic and microscopic characters. All measurements were made using Pro MED software. The specimen was deposited in the herbarium of Panjab University, Chandigarh, India (PAN).

Taxonomy

Dictyocheirospora himachalensis Sushma, Rajn.K. Verma, Prasher, A.K. Gautam, Rajeshk. & R.F. Castañeda **sp. nov.** Figs 1, 2

IF 559461

Differs from *Dictyocheirospora musae* by its bigger conidia

Type —India. Himachal Pradesh: Mandi, Sarkaghat, on bark of *Eucalyptus* sp., 17 July 2015, Sushma (**Holotype**, PAN 31572).

Etymology—the epithet refers to place of collection, Himachal Pradesh

Conidiomata on the natural substrate, sporodochial, scattered, olive to dark blackish brown. Mycelium mostly immersed. Conidiophores hyaline, thin walled, short, 10–12 × 3–4 µm, mostly reduced to conidiogenous cells. Conidiogenous cells monoblastic, cylindrical, determinate, pale brown. Conidia cylindrical-ellipsoidal, smooth walled, pale olivaceous brown, not flattened, 32–48.5 × 14.5–19 µm, truncate at the basal cell, composed of seven appressed rows of 6–8 cells, with 1–3 apical, sub-apical, or central, aseptate, hyaline appendages, 3.5–11.6 µm wide.

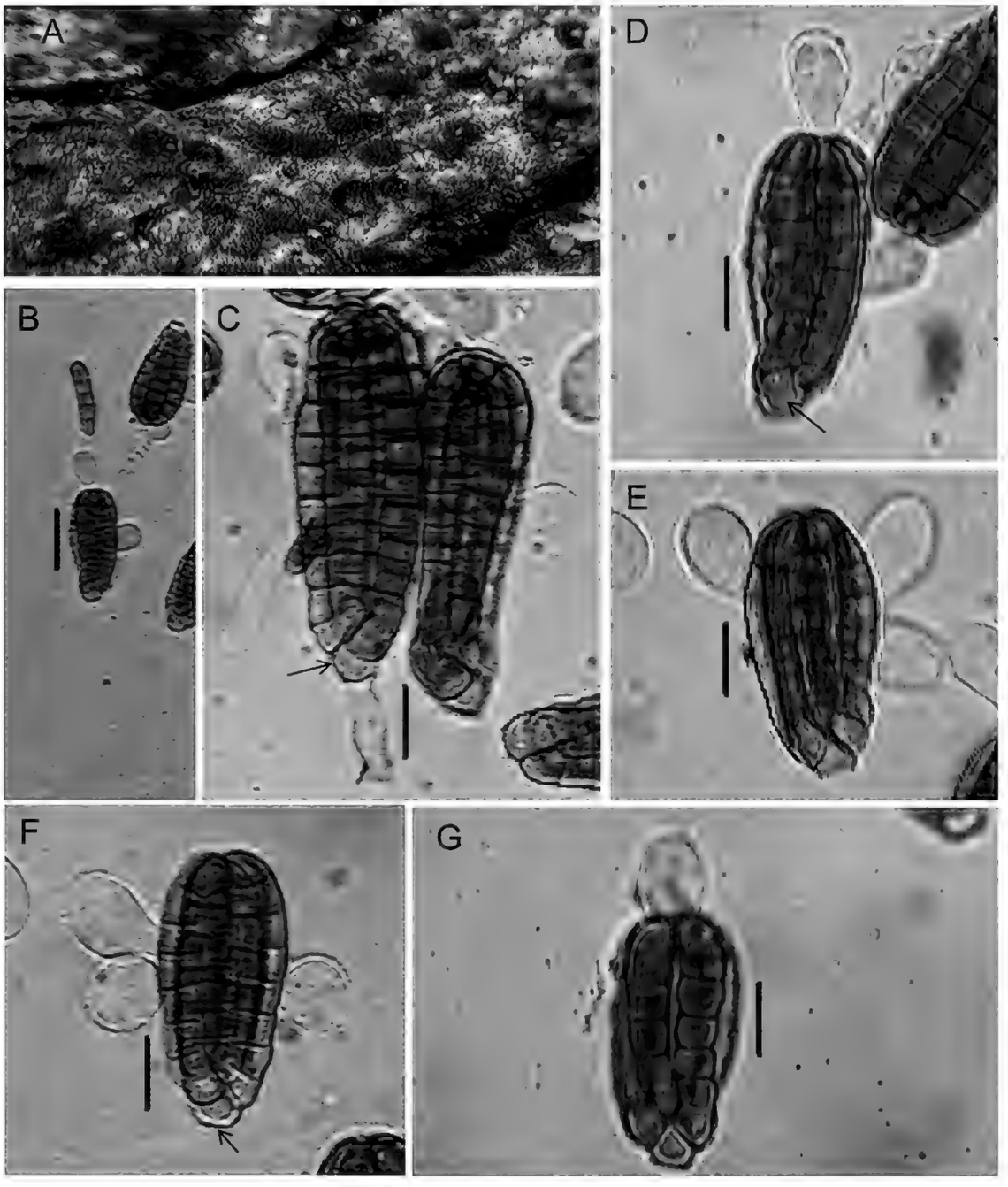

Fig. 1. *Dictyocheirospora himachalensis* (PAN 31572). A. Sporodochia on natural substrate; B–G. Conidia with appendages [C, D, F with arrows showing basal cell]. Scale bars: B = 20 µm; C–G = 10 µm.

Discussion

Dictyocheirospora was established by Boonmee & al. (2016) with *D. rotunda* M.J. D'souza & al. as the type species and proposing two other new species (*D. bannica* and *D. vinaya*) and four new combinations (*D. gigantica*,

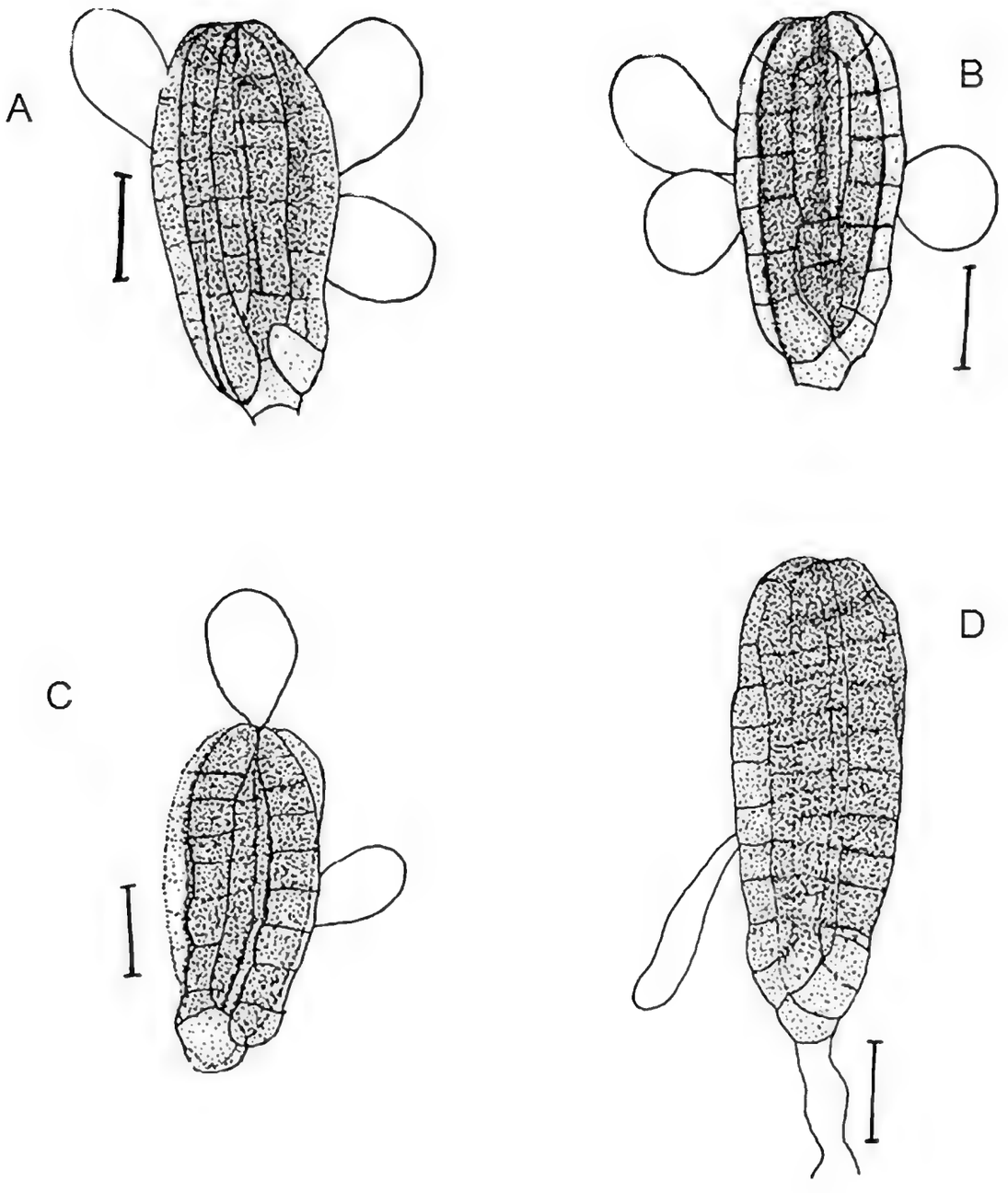

Fig. 2. *Dictyocheirospora himachalensis* (PAN 31572).
Conidia with apical, sub-apical, and central appendages. Scale bars = 10 μm.

D. heptaspora, *D. pseudomusae*, and *D. subramanianii*). Wang & al. (2016), who described two new species, provided a synopsis of the genus. Subsequently 14 additional species and new combinations have been added by Hyde & al. (2017, 2019) Tibpromma & al. (2018), Yang & al. (2018), Jayasiri & al. (2019), Phookamsak & al. (2019), Phukhamsakda & al. (2020), and Dong & al. (2020). Twenty-three species are listed in *Dictyocheirospora* by Index Fungorum 2022.

Six *Dictyocheirospora* species have appendiculate conidia, while 16 species lack conidial appendages; all species are compared in Table 1 (pp. 460–461). *Dictyocheirospora himachalensis* differs from all other appendiculate conidial species in the positioning of its 1–3 conidial appendages, which are apical and central as well as subapical. The new species is distinguished from *Dictyocheirospora hydei* with suprabasal conidial appendages, *D. indica* with complanate conidia and fewer, subapical appendages, and *D. musae* with bigger conidia.

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Table 1. Synopsis of the morphological characters of *Dictyocheirospora* spp.

Species	Appendages			Conidia [µm]		References
	Size [µm]	Position	Shape, number	Size [µm]	Rows of cells	
D. aquadulcis	—	—	—	60–80 × 17–29	7	Hyde & al. 2019
D. aquatica	—	—	—	34–42 × 12.5–19.5	5–6	Wang & al. 2016
D. bannica	—	—	—	73–86 × 21–26	5–7	Boonmee & al. 2016
D. cheirospora	—	—	—	54–63 × 15–26	5–7	Hyde & al. 2017
D. clematidis	—	—	—	42–60 ×15–30	6–7	Phukhamsakda & al. 2020
D. garethjonesii	—	—	—	45.5–54.5 × 15.5–24.5	6–7	Wang & al. 2016
D. gigantica	—	—	—	105–121 × 25–32	7	Goh & al. 1999, Boonmee & al. 2016
D. heptaspora	—	—	—	50–80 × 25–22	7]	Damon 1952, Boonmee & al. 2016
D. himachalensis	3.5–11.6 diam.	Apical, subapical, and central	Variously shaped, 1–3	32–48.5 × 14.5–19	7	Present study
D. hydei	12–15 × 9–14	Basal	Globose to circular, 1–3	30–35 × 14–17	7	Prasher & Verma 2015a, Yang & al. 2018
D. indica	5–13 × 5–7	Subapical	Obovoid; 1–2	36–46 × 13–18	6(–7)	Prasher & Verma 2015a, Yang & al. 2018
D. lithocarpi	—	—	—	35–40 × 12–18	6	Jayasiri & al. 2019

Species	Appendages			Conidia [µm]		References
	Size [µm]	Position	Shape, number	Size [µm]	Rows of cells	
D. metroxyloni	—	—	—	45–69 × 15–29	4–6	Phookamsak & al. 2019
D. musae	12–28 × 3–9	Central	Clavate to obovoid, 1–3	45–65 × 20–27	7	Photita & al. 2002, Yang & al. 2018
D. nabanheensis	5–16 × 5–6.5	Near middle of conidial rows	Rounded to cylindrical; 1–2	35–40 × 18–21	6	Tibpromma & al. 2018
D. pandanicola	—	—	—	60–75 × 18.5–35.5	5–7	Tibpromma & al. 2018
D. pseudomusae	6–11.5	Apical or side of outer rows	(Sub)globose, 1–2	61–78 × 19–29	6–7	Tanaka & al. 2015, Boonmee & al. 2016
D. rotunda	—	—	—	42–58 × 19–38	5–7	Boonmee & al. 2016
D. subramanianii	—	—	—	33–42 × 10–8	7	Sutton 1985, Boonmee & al. 2016
D. taiwanense	—	—	—	74–84 × 16–20	5	Hyde & al. 2019
D. tetraploides	10–25 × 5–10	Subapical	Cylindrical to clavate; 2	52.5–72.5 × 18.5–26.5	5	Cai & al. 2003, Yang & al. 2018
D. thailandica	—	—	—	42–65 × 20–45	6–7	Dong & al. 2020
D. vinaya	—	—	—	58–67 × 15.5–26.5	6–7	Boonmee & al. 2016
D. xishuangbannaensis	—	—	—	35–50 × 17–25	6	Tibpromma & al. 2018

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Lecanora moniliformis sp. nov. from China

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Abstract—A new multispored *Lecanora* species from China is proposed as *L. moniliformis*, which is similar to *L. japonica* but differs by its crenate apothecial margin and the presence of psoromic acid. A detailed taxonomic description, ecological and chemical characters, and illustrations are provided for the new taxon, and a key to the multispored species of *Lecanora* is presented.

Key words—16-spored, taxonomy, *Lecanoraceae*, East Asia, lichenized fungi

Introduction

The *Lecanora subfusca* group, which is the core group of *Lecanora* Ach., is characterized by the presence of oxalate crystals in the amphithecium and the production of atranorin and/or usnic acid in the cortex (LaGreca & Lumbsch 2001). Eleven multispored species belong to the *subfusca* group, and seven of them have been reported from China: *L. bruneri* Imshaug & Brodo, *L. cateilea* (Ach.) A. Massal., *L. japonica* Müll. Arg., *L. loekoesii* L. Lü & al., *L. shangrilaensis* Z.T. Zhao & L. Lü, *L. subjaponica* L. Lü & H.Y. Wang, and *L. weii* L.F. Han & S.Y. Guo (Alstrup 1993; Han & al. 2009; Lü & al. 2012; Lü & Zhao 2017; Nayaka & al. 2006; Wang & al. 2007, 2013).

During a recent study of *Lecanora* from China, we found a new species belonging to the *subfusca* group, which is described here. We also provide a key to the multispored *Lecanora* species.

Materials & methods

The specimens collected from Anhui, Hubei, and Shaanxi are housed in the Lichen Section of the Botanical Herbarium, Shandong Normal University, Jinan, China

(SDNU). Macromorphological characters were examined under a COIC XTL 7045B2 stereomicroscope and photographed using an Olympus SZX16 dissecting microscope. Micromorphological characters, such as apothecial tissues, crystal types, asci, and ascospores, were examined by hand-cut sections under an Olympus CX41 polarizing microscope and photographed using an Olympus BX61 with DP72. Lichen substances were identified using spot tests and standardized thin layer chromatography techniques (TLC) with solvent system C (Orange & al. 2010).

Taxonomy

Lecanora moniliformis L. Lü & Z.T. Zhao, **sp. nov.** Fig 1

MB 812174

Differs from *Lecanora japonica* by its crenate apothecial margin and the presence of psoromic acid.

Type: China. Hubei, Shennongjialinqu, Wenshuilinchang, alt. 1680 m, on bark, 10 Nov. 2010, Z.T. Zhao, 20101715B (**Holotype**, SDNU).

Etymology: The specific epithet refers to the morphology of the apothecial margin.

Thallus crustose; surface dirty gray to greenish gray, continuous, rought to verruculose, esorediate; margin indistinct; prothallus not visible. Apothecia lecanorine, sessile to constricted at the base, 0.4–1.6 mm in diam; disc reddish brown to dark brown, epruinose, plane to convex, plicated; margin concolorous with thallus, thick, entire to flexuose, verruculose to crenate; amphithecium with small crystals insoluble in K, 50–133 µm thick; cortex indistinct, basally not thickened; parathecium hyaline; epihymenium reddish brown to orange brown, pigment insoluble in K, 7.5–12.5 µm thick; hymenium hyaline, with crystals insoluble in K, 50–80 µm thick; subhymenium hyaline, 40–115 µm thick; hypothecium indistinct; paraphyses simple, up to 2.5 µm wide; asci clavate, containing (8–)12–16 spores; ascospores hyaline, simple, ellipsoid, 4–8 × 10–16 µm, wall <1 µm thick. Pycnidia not observed.

Chemistry: cortex K+ yellow, C–, KC–, P–; medulla K+ yellow, C–, KC–, P–; atranorin and psoromic acid present.

Ecology and distribution: This species was found in the mountainous regions of Anhui Province and the forest regions of Hubei and Shaanxi Provinces, central China, at elevations of 1300–1700 m on the bark of *Pinus* sp.

Additional Specimens Examined: **CHINA. Anhui, Liuan city**, Huoshan, Baimajian, alt. 1300 m, on bark, 8 Jun. 2011, H.Y. Wang 20113235 (SDNU); **Shaanxi, Ningshan**, Xilinjidi, alt. 1500 m, on bark, 27 Jul. 2005, W. Fu L-809C (SDNU).

Discussion: This species is characterized by the crenate apothecial margin, (8–)12–16-spores per ascus and the presence of psoromic acid in addition to atranorin. Two other multispored species, *Lecanora japonica* and *L. subjaponica*,

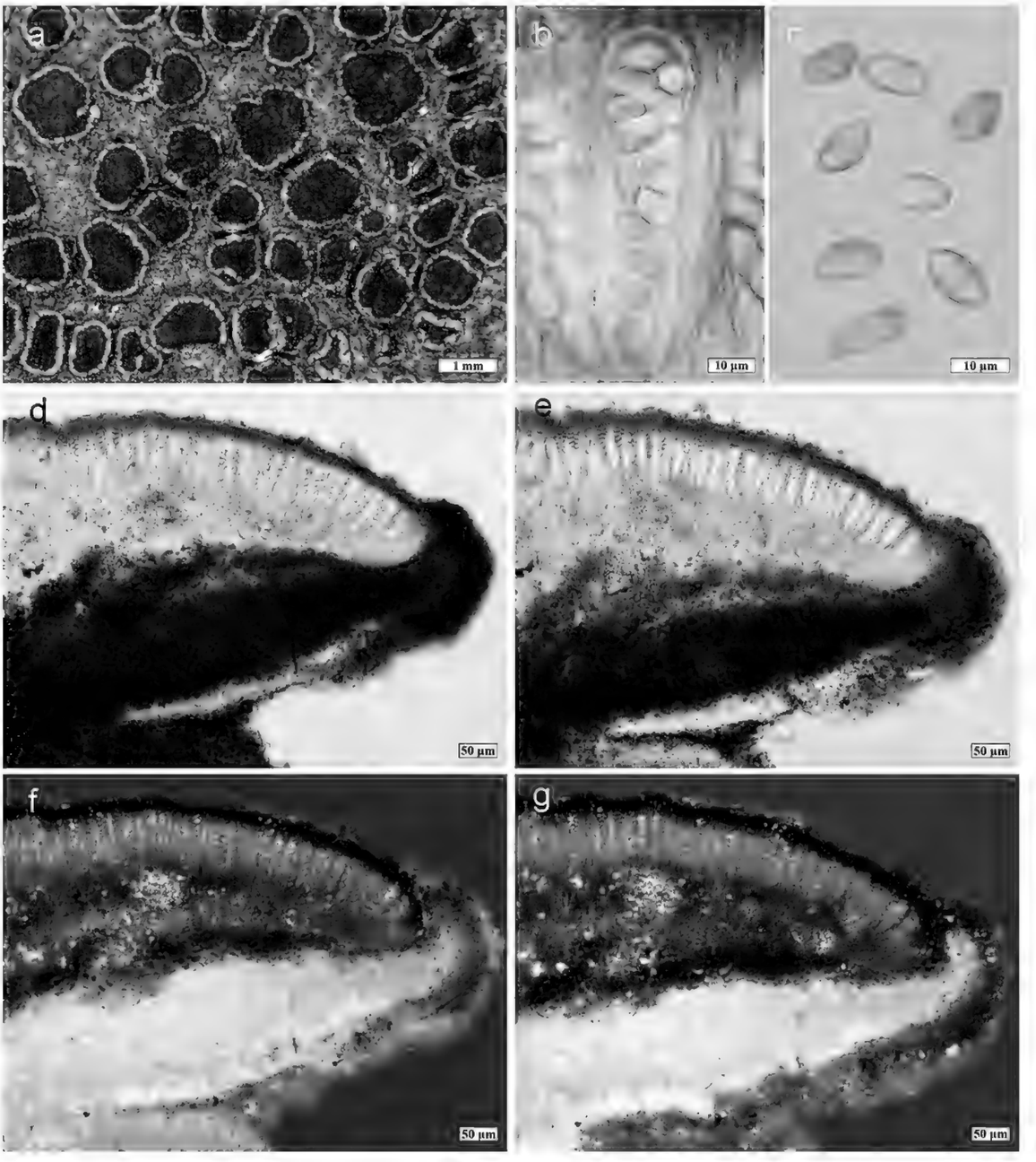

Fig. 1. *Lecanora moniliformis* (holotype, SDNU-Zhao 20101715B): a. Thallus; b. Asci; c. Ascospores; d. Apothecium section; e. Pigment of epihymenium (insoluble in K); f. Crystals of apothecium section; g. Small crystals of amphithecium (insoluble in K).

are similar to *L. moniliformis*. However, *Lecanora japonica* produces atranorin only, while *L. subjaponica* has (16–)32-spores per ascus, contains atranorin and zeorin. Furthermore, both possess an even apothecial margin. *Lecanora argentea* Oxner & A.M. Volkova also has a crenate apothecial margin, but it has 8-spores per ascus and produces gangaleoidin beside atranorin.

Key to the multispored species of *Lecanora*

1. Epihymenium not granulose 2
1. Epihymenium granulose 5
2. Apothecial margin usually verruculose to crenate, asci (8–)12–16-spored, thallus containing atranorin and psoromic acid ..... *L. moniliformis*
2. Apothecial margin usually even, thallus lacking psoromic acid 3
3. Thallus containing atranorin alone; (8–)16-spored ..... *L. japonica*
3. Thallus containing atranorin and zeorin 4
4. Amphithecium with large crystals; 12–16-spored ..... *L. subpraesistens*
4. Amphithecium with small crystals; 16–32-spored ..... *L. subjaponica*
5. Thallus lacking atranorin 6
5. Thallus containing atranorin 7
6. Thallus containing fumarprotocetraric acids; asci 8–12-spored, ascospores simple ..... *L. shangrilaensis*
6. Thallus containing zeorin; asci (12–)16(–32)-spored, ascospores frequently 1-septate ..... *L. strobilinoides*
7. Thallus containing usnic acid 8
7. Thallus lacking usnic acid 9
8. Apothecial disc epruinose or slightly pruinose; epihymenium with fine granules; containing atranorin, norstictic acid and zeorin, as well as usnic acid *L. loekoesii*
8. Apothecial disc heavily pruinose; epihymenium with coarse granules; containing atranorin in addition to usnic acid ..... *L. weii*
9. Amphithecium with large crystals; thallus without psoromic acid 10
9. Amphithecium with small crystals; thallus with psoromic acid 11
10. Prothallus whitish grey; apothecial disc orange-brown to reddish orange; asci 8(–16)-spored ..... *L. pleospora*
10. Prothallus not visible; apothecial disc red-brown to blackish orange; asci (8–)12(–16)-spored ..... *L. praesistens*
11. Apothecia densely clustered; apothecial disc red-brown, pruinose; asci (12–)16-spored ..... *L. bruneri*
11. Apothecia scattered; apothecial disc yellow-brown to orange-brown, slightly pruinose; (8–)12-spored ..... *L. cateilea*

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Didymium dictyosporum sp. nov. from Mexico

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Abstract — A new myxomycete species, *Didymium dictyosporum* from Mexico, is described and illustrated. It is characterized by its sessile to shortly stipitate whitish to greyish fruiting bodies, absence of a capillitium, and reticulate spores. The new species is compared with other morphologically similar myxomycetes. Micrographs of the most important characteristics under LM and SEM are provided.

Key words — *Amoebozoa*, *Myxogastrea*, *Physarales*, slime molds, taxonomy

Introduction

During the last six years, our survey of moist chamber cultures prepared with substrates from different tree species collected in the urban Mexico City area has revealed some new myxomycete species to document the biodiversity of Mexico, including *Perichaena polygonospora* Novozh. & al. (Lizárraga & al. 2016) and *Licea tuberculata* G.W. Martin (Lizárraga & Moreno 2020). We recently obtained fruiting bodies of a *Didymium* species on bark samples from *Populus deltoides* in a moist chamber culture that presented sufficient macroscopic and microscopic differences to be described as a species new to science.

Didymium is represented by 99 species worldwide (Lado, 2022), of which 36 species have been recorded for Mexico (Lado & Wrigley de Basanta 2008, Salazar-Márquez & al. 2013, Lizarraga & al. 2016, Moreno & al. 2017).

Didymium is characterized by its sessile, stipitate, or plasmodiocarpic fruiting bodies superficially covered with crystalline lime, a stipe (when present) that may or may not be calcareous, spores that are black in mass and violaceous to purplish brown as seen through the LM, and a capillitium (when present) comprising threads that are usually abundant but which can be sparse or even absent in some species. Most generic characters are shared with *Mucilago,* which is included in the same family (*Didymiaceae* Rostaf. ex Cooke). The only morphological character separating the two genera is the aethaloid fruiting body in *Mucilago*. Leontyev & al. (2019), however, place the two genera in phylogenetically separate clades.

Materials & methods

Small pieces of bark obtained from living trees were placed in moist chamber cultures following the technique of Stephenson & Stempen (1994). For the microscopic study, specimens were mounted in Hoyer's medium. The SEM study was done with a Zeiss DSM-950 microscope. Ultramicroscopic studies were carried out following the technique described in Lizárraga & al. (2016). The material of the new species was deposited in the Herbarium of the Universidad de Alcalá, Madrid, Spain (AH) and in the Herbarium of Universidad Autónoma de Ciudad Juárez, Chihuahua, Mexico (UACJ).

Taxonomy

Didymium dictyosporum Lizárraga & G. Moreno, **sp. nov.** Fig. 1

MB 843639

Differs from *Didymium atrichum* by its spore reticulum with fewer meshes per hemisphere and higher walls.

Type: Mexico, Mexico City, Parque Tezozomoc, on bark of *Populus deltoides* W. Bartram ex Marshall, placed into moist chamber culture 10–V–2021, obtained 20–VII–2021, leg. M. Lizárraga & H.R. Pelayo (**Holotype**, AH 51461).

Etymology: in reference to the reticulate spores.

Sporocarps clustered to scattered, sessile to shortly stipitate, 0.15–0.2 mm total height. Sporotheca 0.05–0.2 mm diam., whitish to greyish, globose, subglobose to pulvinate. Stipe short, 0.01–0.03 mm long, straw-yellow. Hypothallus inconspicuous. Peridium double, inner layer hyaline, membranous, external layer cartilaginous, smooth, eggshell-like, firm, formed by stellate crystals of calcium carbonate, with irregular dehiscence. Pseudocolumella not observed. Capillitium not observed. Spores black in mass, light violaceous under LM, (9–)10–12(–13) µm diam., globose to subglobose, reticulate to subreticulate. Under SEM, the spore ornamentation

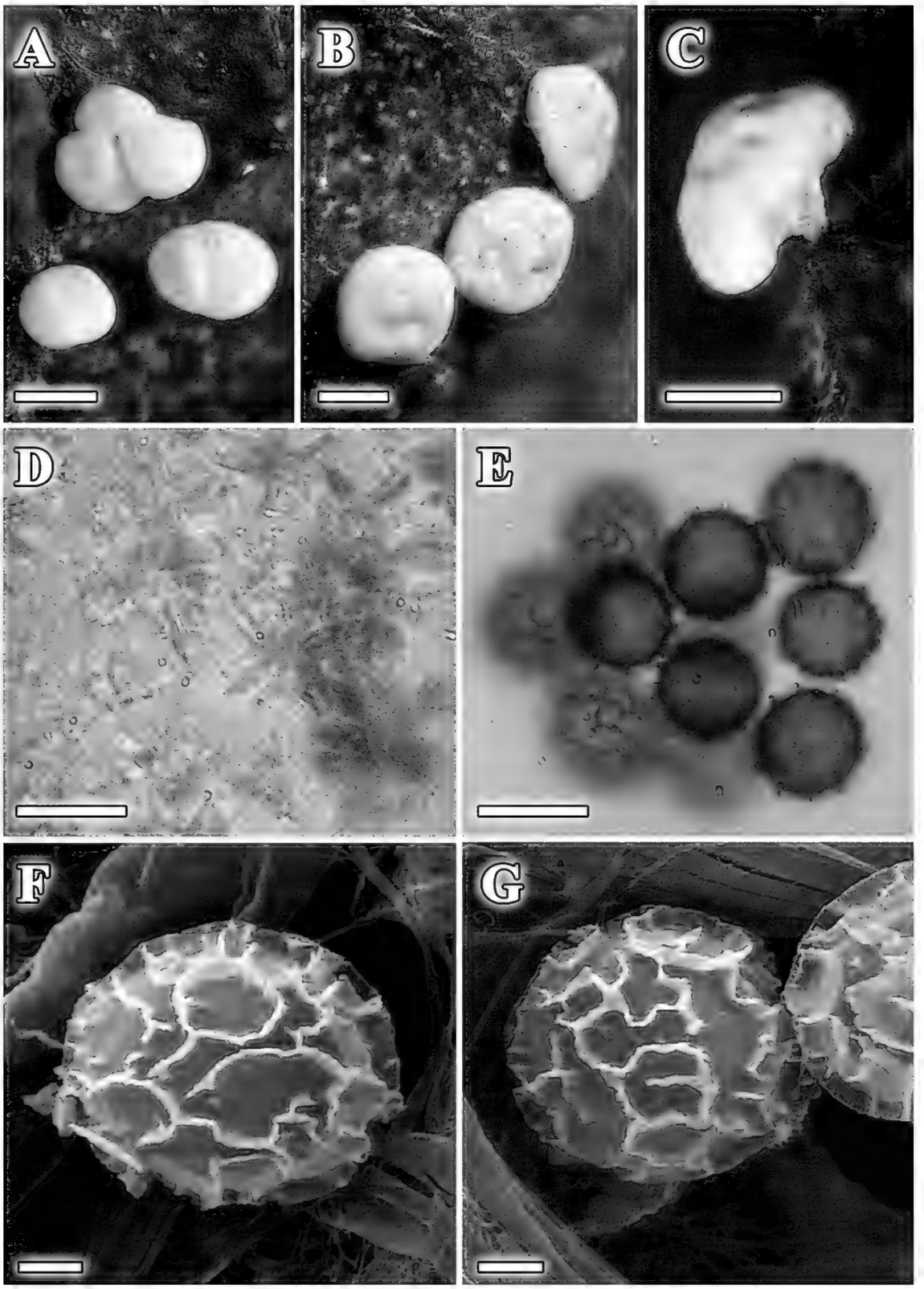

Fig. 1. *Didymium dictyosporum* (holotype, AH 51461): A, B. Fruiting bodies (AH 51462); C. Detail of stipe; D. Peridium crystals (LM); E. Spores (LM); F, G. Spores (SEM). Scale bars: A–C = 0.1 mm; D, E = 10 μm; F, G = 2 μm.

is formed by broad reticules that have 4–7 meshes per hemisphere, with high (≤1 μm) walls lacking perforations and with an irregular to sinuous edge.

Additional specimens examined: **MEXICO. Mexico City**: Parque Tezozomoc, on bark of *Populus deltoides*, placed into moist chamber culture 30–III–2021, obtained 4–VI–2021, leg. M. Lizárraga & H. R. Pelayo (UACJ 3384); obtained 10–VIII–2021 leg. M. Lizárraga & H. R. Pelayo (AH 51462).

Observations—*Didymium dictyosporum* is characterized by its small sessile to short-stipitate fruiting bodies, cartilaginous sporotheca, absence of pseudocolumella and capillitium, and 9–11(–13) μm reticulate spores.

Didymium atrichum Henney & Alexop., is a similar species with spores 10–11 μm diam., "spinulose or faintly reticulate under the light microscope but conspicuously reticulate under the scanning electron microscope" (Henney & al. 1980). The spore reticulum is very different; it has more than 17 meshes per hemisphere and low (≤0.3 μm high walls.

Didymium reticulosporum Novoz. & Zeml., another reticulate spored species, differs mainly by fruiting bodies with a simple membranous peridium, larger (13–16 μm diam.) spores that are reticulate with a basal secondary reticulum that is visible only under SEM and formed by small meshes covering the epispore (Novozhilov & Zemlyanskaya 2006).

Didymium subreticulosporum Oltra & al., also with subreticulate to reticulate spores, is distinguished by a capillitium of calcium carbonate crystals occurring in lines that emerge radially from the central part of the sporocarp. This differs from the typical capillitium formed by hyaline threads found in the genus *Didymium* (Oltra & al. 1997; Lizárraga & al. 1998).

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Astrothelium subsiamense sp. nov. from Fujian, China

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Abstract—A new species, *Astrothelium subsiamense* from China, is described based on morphological, chemical, and molecular analyses. The new lichen is most similar to *A. siamense* but differs in its 3-septate and smaller ascospores. Its relationship with other *Astrothelium* spp. is presented, based on molecular phylogeny, and a key to the *Astrothelium* species recorded in China is also provided.

Key words—lichenized fungi, taxonomy, South China, *Trypetheliaceae*, *Typetheliales*

Introduction

Astrothelium Eschw. (*Trypetheliaceae*, *Trypetheliales*, *Dothideomycetes*) was established by Eschweiler (1824) with *A. conicum* as the type species.

Astrothelium, the largest genus in *Trypetheliaceae*, comprises about 250 species worldwide (Aptroot & Lücking 2016, Wijayawardene & al. 2017, Jiang & al. 2021). The genus was originally limited to species in *Trypetheliaceae* with lateral fused ostioles and transversely septate ascospores (Aptroot & Lücking 2016, Luangsuphabool & al. 2016), but some workers (Harris 1995, Aptroot & al. 2008) considered this circumscription to be vague. Nelsen & al. (2014) have demonstrated that there is a strong conflict between molecular-based phylogeny and traditional morphological classification within *Trypetheliaceae*. With a recent generic rearrangement, *Astrothelium* now includes most species previously recognized as the artificial genera *Astrothelium*, *Campylothelium* Müll. Arg., *Cryptothelium* A. Massal., *Laurera* Rchb., and *Trypethelium* Spreng. (Aptroot & Lücking 2016; Lücking & al. 2016 a,b).

Astrothelium is characterized by a corticate thallus that is mostly olive-green (sometimes pale yellow) with lichexanthone (Hyde & al. 2013), simple to aggregate or pseudostromatic ascomata with apical to lateral and separate or fused ostioles, and ascomata or pseudostromata (either immersed or prominent) with pseudostromata often differing in structure and colour from the thallus. The ascospores in *Astrothelium* are often hyaline, transversely septate with diamond-shape lumina or muriform (Aptroot & Lücking 2016), although *A. fuscosporum* Soto-Medina & al. is known to produce pigmented ascospores (Soto-Medina & al. 2017).

Seven *Astrothelium* species have been previously reported from China: *A. cinnamomeum* (Eschw.) Müll. Arg., *A. variolosum* (Ach.) Müll. Arg., *A. sinense* S.H. Jiang & C. Zhang, *A. macrocarpum* (Fée) Aptroot & Lücking, *A. leucosessile* Lücking & al., *A. siamense* Luangsuph & al., and *A. subinterjectum* Lücking & al. (Aptroot & Seaward 1999; Jiang & al. 2021; Zahlbruckner 1932; Zhang 2020). A report of "*A. speciosum*" from China (Zahlbruckner 1933) is a typographic error for *Anthracothecium speciosum* Zahlbr. (Aptroot & Lücking 2016). Here we report a new species, *A. subsiamense*, as an additional record from Fujian province, South China.

Materials & methods

Specimens, morphology, chemistry

The specimens of the new species were collected from Fujian province of China and deposited in the Fungarium of College of Life Sciences, Liaocheng University, Liaocheng, China (LCUF). The morphology and anatomy were observed and photographed using a Olympus SZX16 dissecting microscope and Olympus BX53 compound microscope. Amyloidity of the ascospores was tested using Lugol's solution. Secondary metabolites were examined by colour test (10% KOH, saturated solution NaClO, and p-phenylenediamine dissolved in ethanol) and thin-layer chromatography (TLC) using solvent C (Culberson 1972, Culberson & Kristinsson 1970).

DNA extraction, PCR sequencing, phylogenetic analysis

Genomic DNA was extracted from ascomata of the specimens using Sigma-Aldrich REDExtract-N-Amp™ Plant PCR Kit according to the manufacturer's protocol and amplified using the ITS1F and ITS4 primer pair (White & al. 1990). The 50 µL PCR reaction system consisted of 2 µL each primer solution, 2 µL genomic DNA, 19 µL ddH_2O, and 25 µL 2×Taq PCR MasterMix. The PCR protocol comprised an initial denaturation for 3 min at 94°C, 35 cycles at 94°C for 30 s + 52°C for 30 s + extension at 72°C for 90 s, and a final extension at 72°C for 10 min. The PCR amplicon was affirmed by electrophoresis on 1% agarose gels and sequenced by Biosune Inc. (Shanghai, China). Since the specimens in this study were slightly old, the genomic DNA was successfully extracted from only one specimen. The newly generated

Table 1. Specimen and sequences used in the phylogenetic analysis

Species	Specimen	GenBank (ITS)
Astrothelium aenascens	HRK93	LC127385
	HRK98	LC127386
A. flavocoronatum	TSL63	AB758900
	KY859	LC127381
A. macrostiolatum	PHL84	LC127389
A. neglectum	TAK8	LC127392
	TAK12	LC127393
	TAK17	LC127394
A. neovariolosum	KY777	LC127390
	KY848	LC127391
A. siamense	KRB105	LC127387
	KRB139	LC127388
A. sinense	GD19282	MT948055
	GD19156	MT948056
A. subsiamense	**FJ19151**	**OM001640**
Trypethelium eluteriae	GD19106	MT420802
	GD19109	MT420803

Note: The new sequence obtained in this study is shown in bold font.

sequence was submitted to GenBank. Sixteen related ITS sequences for phylogenetic tree construction were downloaded from GenBank, and *Trypethelium eluteriae* Spreng. was selected as the outgroup (Jiang & al. 2021) (Table1).

Contigs were assembled and edited using the program Seqman. The ClustalW Multiple alignment and edit were undertaken by Bioedit v. 7.0.5, which yielded final alignment of 652 bp. Maximum likelihood (ML) was performed using the CIPRES Scientific gateway portal (http://www.phylo.org/portal2/; Miller & al. 2010). Maximum likelihood bootstrapping analysis was performed with RAxML-HPC BlackBox v. 8.2.12 (Stamatakis 2014), using the default parameters as implemented on the CIPRES, NSF XSEDE resource with bootstrap statistics calculated from 1000 bootstrap replicates. Generated phylogenetic tree was visualized and edited under Figtree v1.4.2. In addition, Neighbor-Joining analysis was operated on MEGA7 involving 1000 replicates (Kumar & al. 2016).

Phylogenetic results

The maximum likelihood (ML) and Neighbor-Joining analysis (NJ) phylogenetic trees exhibited the same topology; we therefore present only the

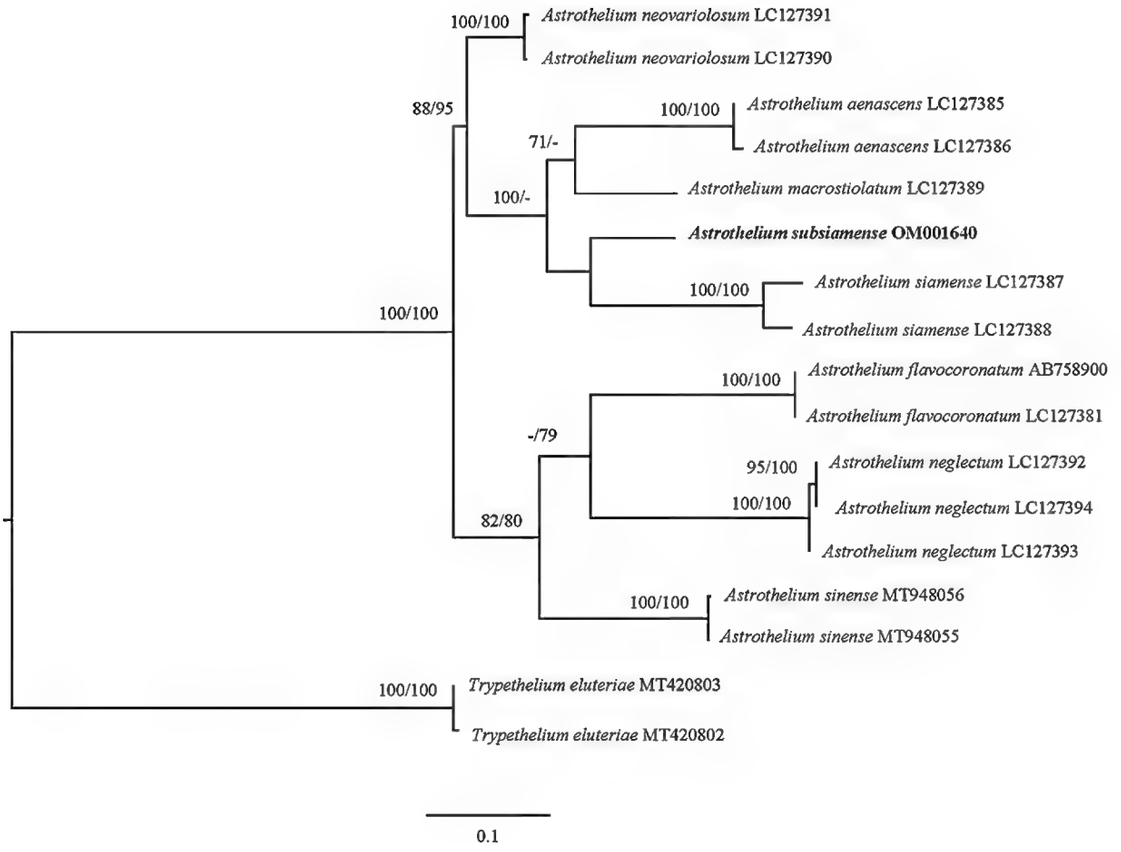

Fig. 1. Phylogenetic tree of *Astrothelium* based on ITS. ML and NJ bootstrap support >70% are shown at the nodes (ML/NJ). The new sequence is set in bold font. Scale bar = 0.1 substitution.

ML tree (Fig. 1), based on 17 ITS sequences from 9 taxa. Both trees supported *Astrothelium subsiamense* as well separated from other *Astrothelium* species and closely related to *A. siamense*.

Taxonomy

Astrothelium subsiamense Y.F. Zhao & Z.F. Jia, **sp. nov.** Fig. 2

FN 570964

Differs from *Astrothelium siamense* by its 3-septate and smaller ascospores.

Type: China. Fujian Province: Quanzhou City, Mt. Jiuxianshan, Natural Observation Path, 25.7122°N 118.1214°E, alt. 1460 m, on bark, 25 Jul. 2019, F.Y. Liu (**Holotype**, LCUF FJ19151; GenBank OM001640).

Etymology: from *sub-* and *siamense*, referring to the similarity with *Astrothelium siamense*.

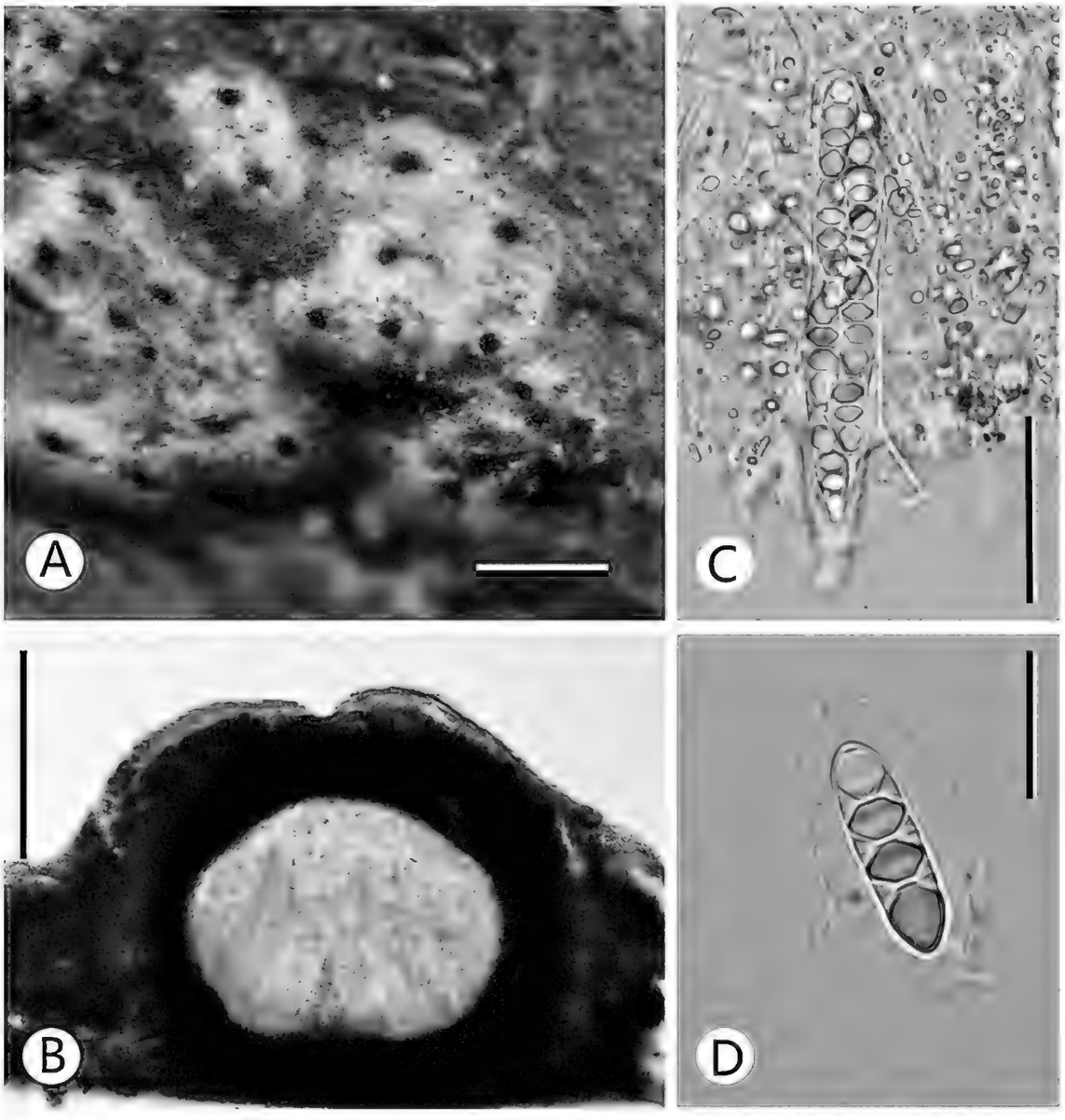

Fig. 2. *Astrothelium subsiamense* (holotype, FJ19151): A. Thallus with ascomata; B. Perithecium section; C. Ascus; D. Ascospores. Scale bars: A = 0.5 mm; B = 200 μm; C = 50 μm; D = 20 μm.

Thallus crustose, corticate, continuous, olive-green to greyish-green, smooth, shiny, 20–40 μm thick; photosynthetic symbiotic alga *Trentepohlia*; ascomata perithecia, pyriform, 0.2–0.5 mm diam, mostly aggregated groups immersed in pseudostromata; pseudostromata pale yellow to white, 0.7–3.5 mm wide; ostioles apical, black, flat to sunk; ascomatal wall carbonized, ≤100 μm thick; hamathecium inspersed with oil droplets; asci hyaline, clavate, 100–114 × 15–20 μm, 8-spored, biseriate; ascospores fusiform, hyaline, 3-septate, with diamond-shape lumina, 20–32 × 7–10 μm, surrounded by gelatinous sheath, 2–9 μm. Pycnidia not seen.

Chemistry—Thallus K+ yellow green, C–, KC–, P–, UV+ yellow. Pseudostromata K+ yellow green, C–, KC–, P–, UV–. TLC: lichenxanthone (thallus).

Ecology & distribution—On bark of subtropic forest park; known only from the type locality in Fujian.

Additional specimen examined: **China**, **Fujian**, **Quanzhou City**, Mt. Jiuxianshan, Natural Observation Path, 25.7122°N 118.1214°E, 25 Jul. 2019, F. Y. Liu (LCUF FJ19157).

Discussion

Astrothelium subsiamense is characterized by its olive-green to greyish-green thallus, mostly aggregated ascomata immersed in pseudostromata, hamathecium inspersed with droplets, and lichenxanthone found only in the thallus. *Astrothelium siamense* and *A. nitidiusculum* (Nyl.) Aptroot & Lücking are morphologically similar to the new species; *A. siamense* differs in its larger ascospores (4–7-septate, 30–50 × 10.5–12.0 µm; (Luangsuphabool & al. 2016), while *A. nitidiusculum* is distinguished by its clear hamathecium without droplets and absence of secondary metabolites (Aptroot & Lücking 2016). Our new species also resembles *A. grossoides* Aptroot & Lücking in having 3-septate ascospores and inspersed hamathecium, but *A. grossoides* has an uneven-bullate thallus and ascomata often containing lichexanthone (Aptroot & Lücking 2016). *Astrothelium subsiamense* shares a similar thallus and ascospores with *A. sinense,* but *A. sinense* has a thicker carbonized ascomatal wall and contains lichenxanthone in its pseudostromata (Jiang & al. 2021).

Key to the species of *Astrothelium* known from China

1. Ascospores 4–7-septate ..... ***A. siamense***
1. Ascospores 3-septate 2
2. Hamathecium clear 3
2. Hamathecium inspersed with oil droplets 6
3. Pseudostromata with yellow to orange pigment 4
3. Pseudostromata without pigment 5
4. Thallus UV– ..... ***A. cinnamomeum***
4. Thallus UV+, yellow ..... ***A. macrocarpum***
5. Thallus UV– ..... ***A. subinterjectum***
5. Thallus UV+, yellow ..... ***A. variolosum***
6. Ascomata forming pseudostromata 7
6. Ascomata simple or aggregated ..... ***A. leucosessile***
7. Pseudostromata UV– ..... ***A. subsiamense***
7. Pseudostromata UV+, yellow ..... ***A. sinense***

Acknowledgments

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Neoveronaea sinensis gen. & sp. nov. from Jiangxi, China

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Abstract—A new hyphomycete genus and species, *Neoveronaea sinensis,* is described from Jiangxi Province, southern China. *Neoveronaea* is characterized by its macronematous conidiophores, and euseptate, obovoid to ellipsoidal, pale brown, smooth conidia. Phylogenetic analyses of partial DNA sequences of internal transcribed spacer (ITS) and nuclear ribosomal large subunit (LSU), using Maximum-Likelihood and Bayesian Inference, reveal the taxonomic placement of *Neoveronaea* within the *Herpotrichiellaceae*, in which it forms a lineage distinct from other genera.

Key words—asexual *Ascomycota*, *Chaetothyriales,* systematics

Introduction

China is located in eastern Asia on the west coast of the Pacific Ocean. It is considered an important reservoir of biodiversity with its unique geography and ecology (Wang 1992). However, its mycobiota, especially saprobic microfungi, are poorly known (Ma & al. 2014, Qiu & al. 2021). During our continuing surveys of asexual fungi occurring on plant debris in forest ecosystems of southern China, we collected an interesting fungus on dead branches of an unidentified broadleaf tree in Meiling National Forest

Park of Jiangxi Province, China. Close examination showed remarkable differences from all previously described hyphomycetes (Seifert & al. 2011), and its morphological identity was confirmed by molecular phylogenetic analyses. It is proposed here as a new genus, *Neoveronaea*.

Materials & methods

Isolates and morphological analyses

Samples of dead branches were collected from humid environments and a riverbank in Meiling National Forest Park (Jiangxi Province, China) and returned to the laboratory in Ziploc™ bags. Samples were processed and examined following the methods described in Ma & al. (2011). Fungi were mounted in a drop of lactic acid on microscope slides and examined and photographed with an Olympus BX 53 microscope with a 100× oil immersion objective. Adobe Photoshop 7.0 was used to assemble photographs into images. Single-spore isolates were cultured on potato dextrose agar (PDA) following Goh (1999). Colony colors were coded according to Rayner (1970). All fungal strains were stored in 10% sterilized glycerin at 4°C for further studies. The studied specimens were deposited in the Herbarium of Jiangxi Agricultural University, Plant Pathology, Nanchang, China (HJAUP), and cultures were deposited in the Jiangxi Agricultural University Culture Collection (JAUCC).

DNA extraction, PCR amplification and sequencing

Genomic DNA was extracted from fungal mycelia grown on PDA using the Solarbio Fungi Genomic DNA Extraction Kit following the manufacturer's protocol. The DNA was amplified by polymerase chain reaction (PCR), using the primer pairs ITS5/ITS4 (White & al. 1990) for the internal transcribed spacer regions with intervening 5.8S nrRNA gene (ITS), and 28S1-F/28S3-R (Ma & al. 2015) for the partial large subunit (LSU) nrRNA gene. PCR reaction volumes were 25 µl containing 1 µl DNA template, 1 µl of each forward and reverse primer, 12.5 µl 2× Power Taq PCR MasterMix, and 9.5 µl ddH_2O. PCR thermal cycling conditions were initialized at 94°C for 3 min, followed by 35 cycles of denaturation at 94°C for 30 s, annealing at 55°C for 50 s, elongation at 72°C for 1 min, a final extension at 72°C for 10 min, and then stored at 4°C. The PCR products were checked on 1% agarose gel electrophoresis stained with ethidium bromide. Purification and DNA sequencing were carried out at Beijing Tsingke Biotechnology Co., Ltd. China.

Sequence alignment and phylogenetic analyses

Phylogenetic analyses were performed on concatenated ITS and LSU sequence data. Sequences generated from this study were analyzed with other similar sequences obtained from GenBank (Table 1). The sequences (Table 1) were initially aligned using MAFFTv.7 (Katoh & Standley 2013) on the online server (http://maffTh.cbrc.jp/alignment/server/) and optimized manually when

Table 1. Isolates and sequences used in the phylogenetic analyses. New sequences are in bold.

Species	Voucher	Accession no.		Reference
		ITS	LSU	
Cladophialophora carrionii	CBS 160.54	EU137266	FJ358234	de Hoog & al. 2007, Gueidan & al. 2008
C. parmeliae	CBS 129337	JQ342180	JQ342182	Diederich & al. 2013
	CBS 132232	JQ342180	JX081671	Diederich & al. 2013
Cyphellophora oxyspora	CBS 698.73	KC455249	KC455262	Réblová & al. 2013
C. sessilis	CBS 243.85	EU514700	EU514700	Réblová & al. 2013
Exophiala jeanselmei	CBS 507.90	—	FJ358242	Gueidan & al. 2008
E. nigra	dH 12,296	NR111131	FJ358244	Gueidan & al. 2008
E. pisciphila	AFTOL-ID 669	—	DQ823101	Gueidan & al. 2008
E. salmonis	AFTOL-ID 671	NR121270	EF413609	Geiser & al. 2006
E. xenobiotica	CBS 115831	AY857539	FJ358246	Gueidan & al. 2008
Fonsecaea monophora	CBS 102243	EU938579	FJ358247	Gueidan & al. 2008, Najafzadeh & al. 2009
Minimelanolocus aquaticus	MFLUCC15-0414	KR215607	KR215612	Liu & al. 2015
M. curvatus	MFLUCC15-0259	KR215605	KR215609	Liu & al. 2015
M. melanicus	MFLUCC15-0415	KR215608	KR215613	Liu & al. 2015
M. submersus	KUMCC15-0206	KX789212	KX789215	Liu & al. 2015
M. thailandensis	MFLUCC15-0971	MG922573	MG922577	Dong & al. 2018
Neoveronaea sinensis	**JAUCC M0840-1**	**OM832969**	**OM832968**	**This study**
	JAUCC M0840-2	**OM833054**	**OM832967**	**This study**
Phialophora macrospora	MUCL 9760	AF050281	AF050281	Untereiner & Naveau 1999
Ramichloridium anceps	AFTOL-ID 659	—	DQ823102	James & al. 2006
Thysanorea papuana	CBS 212.96[1]	NR111276	—	Arzanlou & al. 2007
	CBS 212.96[2]	EU041814	EU041871	Arzanlou & al. 2007
Veronaea botryosa	CBS 254.57	EU041816	EU041873	Arzanlou & al. 2007
V. compacta	CBS 268.75	EU041819	EU041876	Arzanlou & al. 2007
V. japonica	CBS 776.83	EU041818	EU041875	Arzanlou & al. 2007

[1]Ex-holotype culture.

[2]Ex-type culture.

needed. Phylosuite software v1.2.1 (Zhang & al. 2020) was used to construct the phylogenetic tree based on ITS + LSU sequence data. The concatenated aligned dataset was analyzed separately using Maximum likelihood (ML) and Bayesian inference (BI) methods. Maximum likelihood phylogenies were inferred by using IQ-TREE (Anisimova & al. 2011; Nguyen & al. 2015) under the Edge-linked partition model for 1000 standard bootstraps. For both analyses, the optimal ML

tree search was conducted with 1000 separate runs using the default algorithm of the program from a random starting tree for each run. The final tree was selected among suboptimal trees from each run by comparing the likelihood scores using the TIM2+F+I+G4 substitution model. Bayesian Inference phylogenies were inferred using MrBayes 3.2.6 (Ronquist & al. 2012) under the partition model (2 parallel runs, 2,000,000 generations), in which the initial 25% of sampled data were discarded as burn-in. The best-fit model was GTR+I+G for ITS and LSU. These trees were viewed in FigTree v. 1.4.4 (http://tree.bio.ed.ac.uk/software/figtree) and the trees were created in Adobe Illustrator CS v. 5. Newly generated sequences were deposited in GenBank. In this study, the recommendations of Jeewon & Hyde (2016) were followed to determine a new genus.

Phylogenetic results

The ITS and LSU phylogenetic analyses indicated the relationships between the new genus *Neoveronaea* and its morphologically similar genera within the *Herpotrichiellaceae* (Fig. 1). The concatenated aligned dataset comprises

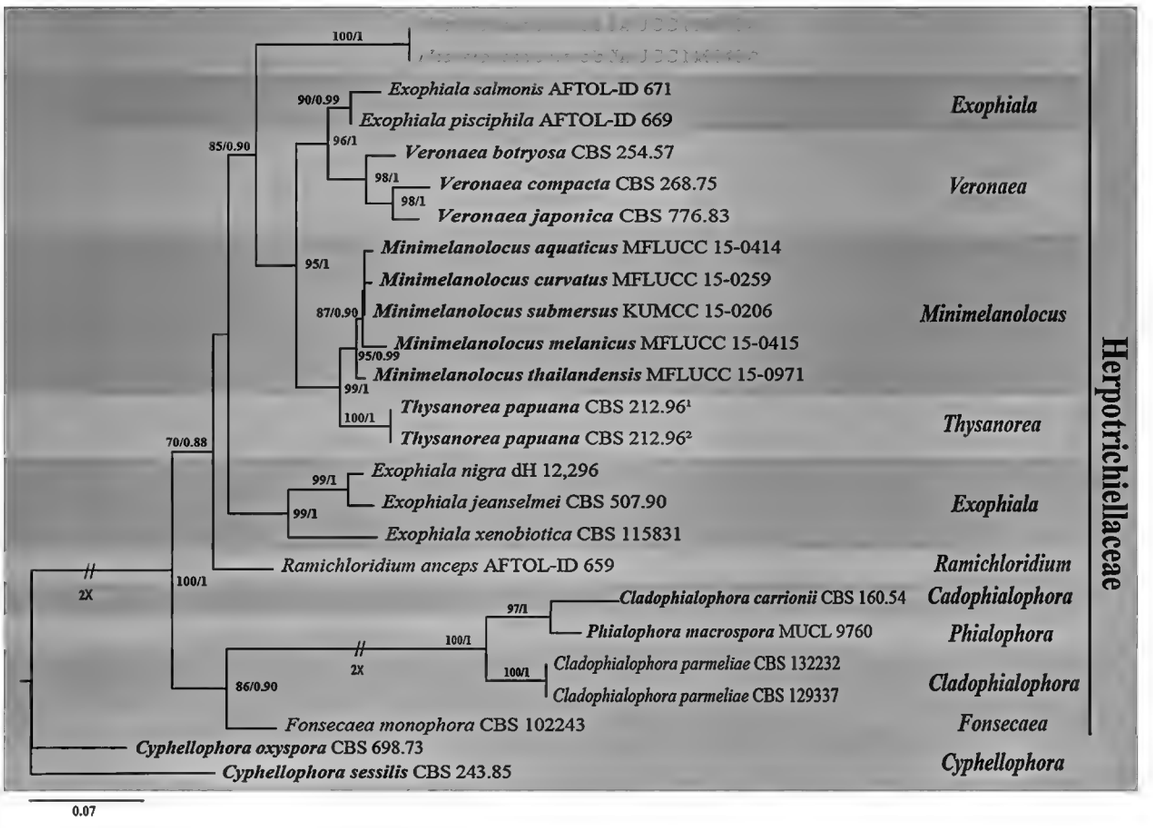

Fig. 1 Phylogenetic tree inferred from maximum likelihood and Bayesian inference analysis based on a concatenated alignment of ITS and LSU sequences. Significant ML/BI bootstrap support values are shown at the nodes. Ex-type isolates are in bold, and newly generated sequences are indicated in red. The tree is rooted to *Cyphellophora sessilis* (CBS 243.85) and *C. oxyspora* (CBS 698.73).

25 isolates representing 22 species, including *Cyphellophora oxyspora* (CBS 698.73) and *C. sessilis* (CBS 243.85) as the outgroup. Maximum likelihood and Bayesian Inference analyses of the combined dataset resulted in phylogenetic reconstructions with largely similar topologies, and the best scoring RAxML tree is shown in Fig. 1. Our two strains clustered with species of *Exophiala*, *Veronaea*, *Minimelanolocus*, and *Thysanorea*, forming a distinct clade with moderately strong bootstrap support (ML = 85%; BI = 0.90) within *Herpotrichiellaceae,* supporting our strains as represented a new genus in that family.

Taxonomy

Neoveronaea L. Qiu, K. Zhang, R.F. Castañeda & Jian Ma, **gen. nov.**

IF 559597

Differs from *Veronaea* by its conidiogenous cells with inconspicuous, slightly prominent, minutely denticles.

Type species: *Neoveronaea sinensis* L. Qiu & al.

Etymology: *Neoveronaea* = "*neo-*" + "*veronaea*" (Lat.), in reference to its similarity to the genus *Veronaea*.

Colonies on substrate natural effuse, pale brown to dark brown; mycelium partly immersed in the substrate, composed of branched, septate, smooth, pale brown to brown hyphae. Conidiophores macronematous, mononematous, erect, straight or slightly flexuous, cylindrical, unbranched, septate, smooth, brown to dark brown. Conidiogenous cells polyblastic, integrated, terminal and intercalary, sympodially extending, with tiny denticles, pale brown. Conidial secession schizolytic. Conidia solitary, acropleurogenous, obovoid to ellipsoidal, euseptate, smooth, pale brown.

Neoveronaea sinensis L. Qiu, K. Zhang, R.F. Castañeda & Jian Ma, **sp. nov.** Fig. 2

IF 559598

Differs from *Veronaea* spp. by its conidiogenous cells with inconspicuous, slightly prominent, tiny denticles, and conidia obovoid to ellipsoidal, 1–3-euseptate.

Type: China, Jiangxi Province: Nanchang, Meiling National Forest Park, 28.7760°N 115.7326°E, on dead branches of an unidentified broadleaf tree, 10 July 2020, L. Qiu (**Holotype**, HJAUP M0840; ex-type living cultures [metabolically inactive by lyophilization] JAUCC M0840-1, M0840-2; GenBank OM832967, OM832968, OM832969, OM833054).

Etymology: refers to the country in which the fungus was collected.

Colonies effuse, scattered, pale brown to dark brown. Mycelium superficial, and immersed in the substrate, composed of branched, septate, pale brown to

brown, smooth hyphae. Conidiophores macronematous, mononematous, unbranched, erect, straight or slightly flexuous, cylindrical, septate, brown to dark brown, paler towards the apex, smooth, thick-walled, 85–120 × 2.5–5 µm. Conidiogenous cells polyblastic, integrated, terminal and intercalary, indeterminate, sympodially extending, cylindrical, with inconspicuous tiny denticles, pale brown, smooth. Conidial secession schizolytic. Conidia solitary, acropleurogenous, dry, obovoid to ellipsoidal, base obconical-truncate, apex rounded, 1–3-euseptate, pale brown, smooth, dry, 7.5–14.5 × 2–5.5 µm.

Culture characteristics: Colonies on PDA media, reaching 30 mm diameter in 20 days at 25°C, buff-yellow, reverse dark olivaceous, velvety, dry, fairly dense, margin entire to sub-undulate.

Discussion

Neoveronaea is unique in its macronematous unbranched conidiophores and solitary, acropleurogenous, euseptate, obovoid to ellipsoidal, pale brown, smooth conidia that secede schizolytically from polyblastic, sympodially extending, terminal and intercalary, integrated conidiogenous cells with inconspicuous, slightly prominent, tiny denticles. It superficially resembles *Veronaea* Cif. & Montemart., but *Veronaea* differs by its cicatrized conidiogenous cells with flattened scars that are faintly pigmented and not thickened (Ellis 1971). *Neoveronaea* is also similar to the genera *Minimelanolocus* R.F. Castañeda & Heredia, *Dactylaria* Sacc., *Pleurophragmium* Costantin, *Rhodoveronaea* Arzanlou & al., and *Veronaeopsis* Arzanlou & Crous in conidial ontogeny, but *Minimelanolocus* differs in its conidiogenous cells with inconspicuous or slightly prominent, narrow, opaque, refractive to somewhat obscure conidiogenous loci (Castañeda-Ruíz & al. 2001). *Dactylaria, Pleurophragmium*, *Rhodoveronaea*, and *Veronaeopsis* differ by their terminal conidiogenous cells with prominent denticles (Ellis 1971, Arzanlou & al. 2007, Seifert & al. 2011). Both morphological and molecular data support our monotypic *Neoveronaea* as a new genus.

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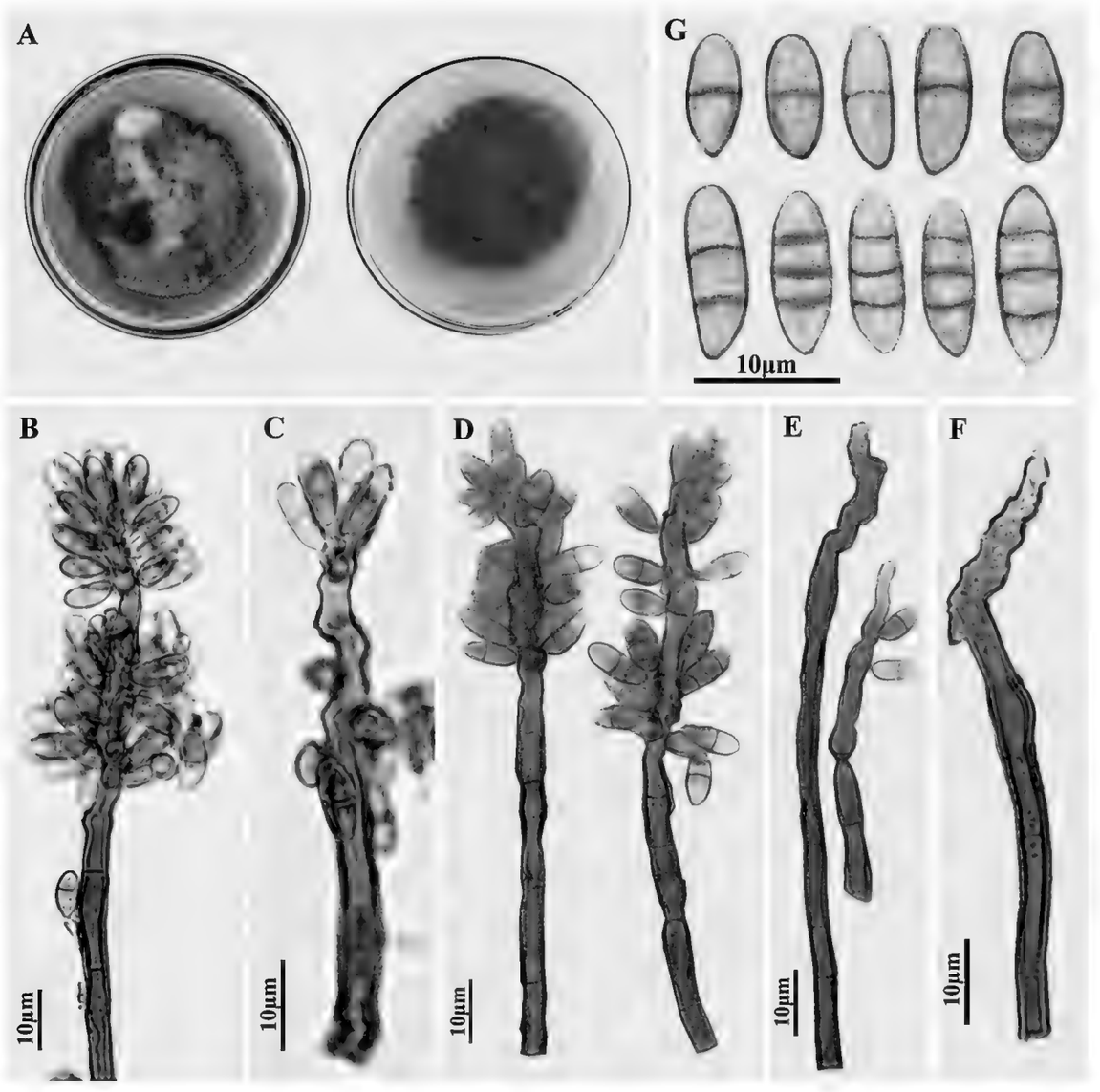

Fig. 2 *Neoveronaea sinensis* (holotype, HJAUP M0840). A. Colony on PDA (surface and reverse); B–D. Conidiophores without the basal part, conidiogenous cells, and conidia; E. Conidiogenous cells and conidia; F. Conidiogenous cell; G. Conidia.

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Mucor septatiphorus nom. nov. and other *Mucor* species recorded from the Brazilian upland forest

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Abstract—During a survey of mucoralean diversity in three different fragments of upland forest located in the semi-arid region of Pernambuco, Brazil, 14 species of *Mucor* were recorded; twelve of them reported for the first time from upland forest areas. We propose a replacement name for *Mucor septatus* nom. illeg. and present detailed descriptions and illustrations of the specimens isolated.

Key words—*Mucoraceae*, *Mucoromycota*, soil, taxonomy, zygosporic fungi

Introduction

The semi-arid region of Brazil has broad phytophysiognomic heterogeneity. The forest formations in these regions comprise the upland forests, or 'Brejos Nordestinos,' which are fragments of humid forests surrounded by caatinga vegetation, a predominant vegetation type in the Brazilian semiarid region (Tabarelli & Santos 2004). These areas are refuges for organisms within the semi-arid domain and are associated with the occurrence of plateaus that confer mild climatic conditions and higher vegetation cover to the region, compared to the surrounded semi-arid ecosystems (Medeiros & Cestaro 2019).

Unfortunately, the Brazilian upland forests have undergone a continuous and systematic process of environmental degradation due to the unsustainable and intense consumption of their environmental assets (Medeiros & Cestaro 2019). These factors compromise the quality of the original ecosystems and cause serious erosion processes, leading to a huge loss of biodiversity (Freire & al. 2018).

Studies have reported the high diversity of *Mucoromycota* Doweld in different Brazilian ecosystems (Lima & al. 2016, 2018b, Souza & al. 2018, Flora e Funga do Brasil 2022); nevertheless, data are still scarce on fungal communities as well as the ecological relationships of these microorganisms with substrates and with other organisms in these ecosystems. Only 37 species of this phylum (including three *Mucor* spp.: *M. souzae*, Crous & al. 2018; *M. septatum* [nom. illeg.], Souza & al. 2018; and *M. pernambucoensis*, Lima & al. 2018c) have been reported from the Brazilian upland forest, but this probably does not reflect the true richness of *Mucoromycota* in these ecosystems.

Mucor Fresen. is the most representative genus in terms of number of species in *Mucoromycota*, and Wijayawardene & al. (2022) estimated around 98 valid species for this genus. *Mucor* species are characterized by the production of non-apophysed sporangia on simple or branched sporangiophores that arise directly from the substrate, while basal rhizoids and stolons are not produced (Benny & al. 2014). Species of *Mucor* may occur as heterothallic (majority) or homothallic forms, and zygospores have almost equal opposite suspension cells without appendages (Hoffmann & al. 2013). Although most *Mucor* representatives are saprobic, some have been reported as opportunistic pathogens causing deep, systemic, and cutaneous mycoses in humans, such as *M. circinelloides*, *M. indicus*, *M. irregularis*, *M. racemosus* Fresen., and *M. ramosissimus* Samouts. (Álvarez & al. 2011, Hoffmann & al. 2013). Voglmayr & Clémençon (2016) described *M. lilianae* Voglmayr & Clémençon and *M. rudolphii* Voglmayr & Clémençon as endoparasites of hypogeous *Hysterangium* basidiomes based on SSU, ITS, and LSU (rDNA)sequences and zygospore morphology, thus expanding the knowledge on the ecological niches of the genus. Several *Mucor* taxa are utilized in biotechnological processes due to their capacity to produce enzymes and organic acids (Kosa & al. 2018).

In view of the ecological and biotechnological importance of *Mucoromycota* and motivated by the constant process of degradation of the Brazilian upland forests, we assessed the *Mucor* communities in soils from upland forests in

the semi-arid region of Pernambuco State to expand the knowledge on the geographical distribution of these fungi. We also describe and illustrate the specimens isolated.

Materials & methods

Study site and soil sampling

The soils were sampled monthly in three upland forest areas in the semi-arid region of Pernambuco, Brazil, during July–December 2016: Brejo da Serra do Bituri (Brejo da Madre de Deus municipality), Brejo de Taquaritinga do Norte (Taquaritinga do Norte municipality), and Brejo do Sítio Carro Quebrado (Triunfo municipality). The samples were placed in plastic bags, kept in polystyrene boxes with ice, and taken to the laboratory.

Isolation, purification, and identification of *Mucor* species

Five milligrams of soil were sprinkled on the surface of wheat germ agar culture medium (Benny 2008) plus chloramphenicol (80 $mg.L^{-1}$) in Petri dishes, performed in triplicate. The Petri dishes were stored for 72 h (28 ± 2°C) under alternating 12 h periods of light and dark. For purification, fragments of colonies were transferred separately to Petri dishes with malt extract agar (Benny 2008) plus chloramphenicol (80 $mg.L^{-1}$). Fragments of selected fertile areas of colonies removed from the Petri dishes for analyses of fungal structures were placed (along with a drop of 3% KOH) onto microscope slides and observed under Zeiss Axioscope 40 light microscope. Seventy measurements were made for each fungal structure. The *Mucor* taxa were identified by analyzing macroscopic (colony color, appearance, diameter) and microscopic (microstructures) characters, as described by in the literature (Schipper 1973, 1975, 1976, 1978; Pei 2000; Madden & al. 2012; Li & al. 2016; Crous & al. 2018; Souza & al. 2018; Lima & al. 2017; Wagner & al. 2019). Living cultures of isolated *Mucor* spp. are deposited at the URM culture collection, Universidade Federal de Pernambuco, Recife, Brazil (URM).

Data of distribution and habitat

Information on the distribution and habitat of *Mucor* spp. was obtained from scientific manuscripts, culture collection vouchers, the Global Biodiversity Information Facility GBIF (https://www.gbif.org), GenBank (https://www.ncbi.nlm.nih.gov/genbank), Flora e Funga do Brasil (http://floradobrasil.jbrj.gov.br), and the plutoF platform (https://plutof.ut.ee).

Culture isolation results

We isolated 14 *Mucor* species: *M. circinatus*, *M. circinelloides*, *M. griseocyanus*, *M. guilliermondii*, *M. hiemalis*, *M. inaequisporus*, *M. indicus*, *M. irregularis*, *M. jansseni*, *M. lusitanicus*, *M. luteus*, *M. septatus* [nom. illeg., renamed below], *M. souzae*, and *M. variicolumellatus*.

Taxonomy

Mucor circinatus D.X. Lima, G. Walther & A.L. Santiago,
Phytotaxa 329(3): 271 (2017) Fig. 1A–D

Colony initially white becoming yellowish brown, reverse cream, colonizing the entire Petri dish (9 cm diam., 0.5 cm high) in 4 days at 25°C on malt extract agar (MEA). Sporangiophores hyaline to slightly light gray, with slightly rough walls, sympodially branched, 2.5–18 µm diam., recurved, growing directly from the substrate, circinate, often arising in the curvature of the previous branch next to the septum. Sporangia light yellow then becoming brown, globose (16–)20–35(–55) µm diam., smooth-walled, wall persistent. Columellae hyaline, globose to applanate (12–)17.5 × 30(–45) µm diam., smooth-walled. Sporangiospores hyaline, angular, 4 × 6.5(–7.5) µm, smooth-walled. Zygosporangia not observed.

Specimen examined—**BRAZIL, Pernambuco, Taquaritinga do Norte**, Brejo de Taquaritinga do Norte, 7.9078°S 36.0403°W, soil samples, 1056 m a.s.l., soil samples, 5.XI.2016, C.A.F. Souza (URM 7774).

Habitat—Different soil types (Zycha 1935, Peries & al. 1979, Souza & al. 2011, Lima & al. 2017).

Geographic distribution—Australia, Brazil, Colombia, Malaysia, South Africa, Sri Lanka, Taiwan.

Comments—The morphological characteristics of URM 7774 (e.g., circinate sporangiophores ≤18 µm diam.; angular sporangiospores mostly 4 × 6.5 µm) correspond well to those described by Lima & al. (2017). This is the first report of *M. circinatus* in the Brazilian upland forest.

Mucor circinelloides Tiegh.,
Ann. Sci. Nat., Bot., sér. 6, 1: 94 (1875) Fig. 1E–H

Colony initially yellowish white, becoming yellowish gray to brownish, reverse yellow, colonizing the entire Petri dish (9 cm diam., ≤1 cm high) in 5 days at 25°C, on MEA. Sporangiophores hyaline to light gray, some with yellowish content, slightly encrusted-walled, repeatedly sympodially branched, with long and short branches, erect or slightly recurved; short sporangiophores more profusely branched with short and often circinate branches, ≤18 µm diam. Sporangia initially yellowish becoming brownish grey at maturity, globose, 35–85(–90) µm diam., with smooth and slightly incrusted wall. The wall of larger sporangia is deliquescent, persistent in the smallest ones. Columellae hyaline to brownish grey, globose, 10–35 µm diam., obovoid to slightly ellipsoidal, 20–60(–65) × 20–45 µm, smooth-walled,

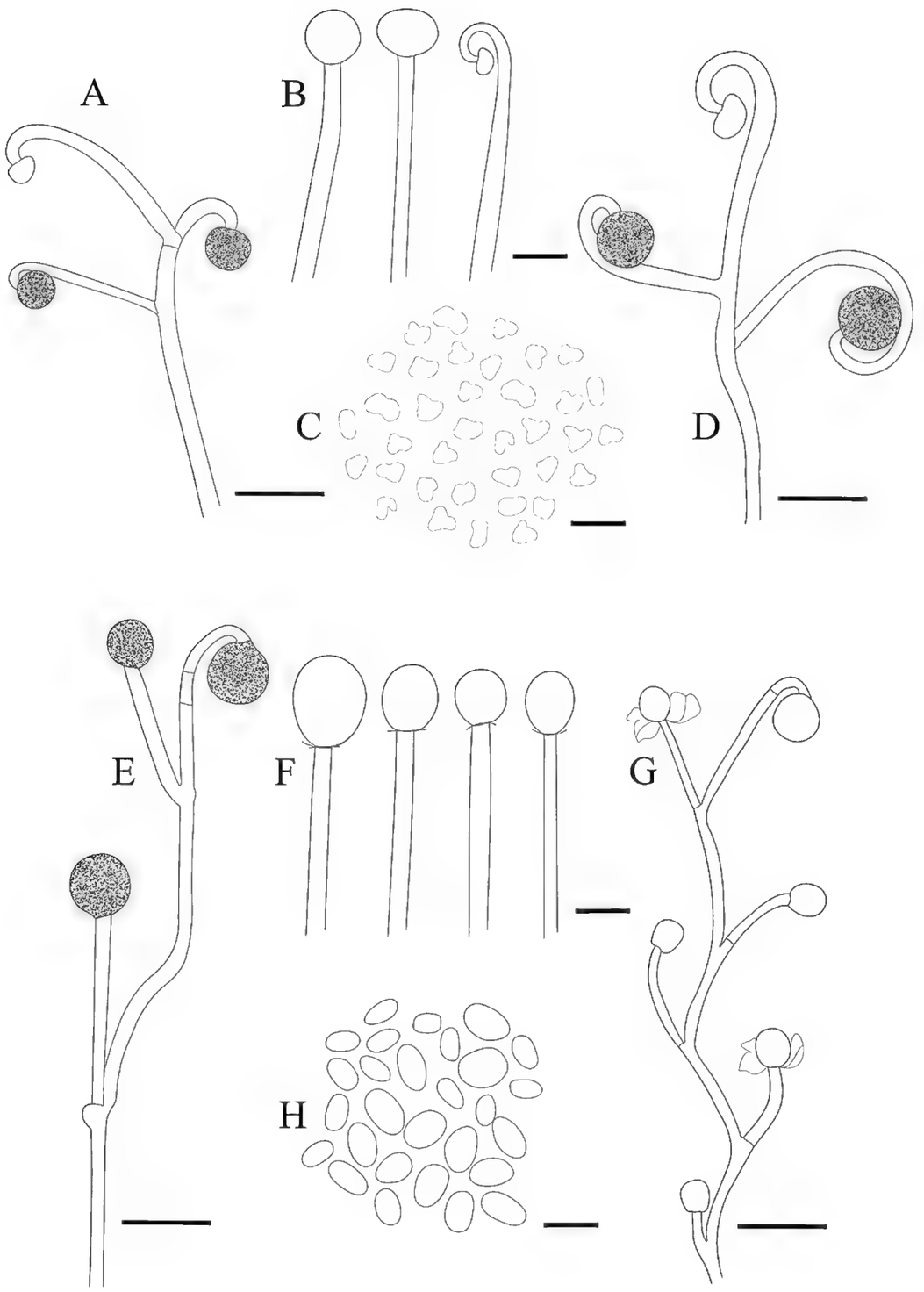

Fig. 1. ***Mucor circinatus*** (URM 7774): A. Branched circinate sporangiophores with sporangia and columella; B. Unbranched sporangiophores with columellae; C. Angular sporangiospores; D. Branched circinate sporangiophore with sporangia and columella; ***Mucor circinelloides*** (URM 7770): E. Branched sporangiophore with sporangia; F. Unbranched sporangiophores with columellae; G. Repeatedly sympodially branched sporangiophore with sporangium and columellae; H. Ellipsoid sporangiospores. Scale bars = 20 µm.

collar common. Sporangiospores hyaline, ellipsoid 4–9 × 3.5–6.5 µm, smooth-walled. Zygosporangia not observed.

Specimen Examined—**BRAZIL, Pernambuco, Brejo da Madre de Deus**, Brejo da Serra do Bituri, 8.1833°S 36.4000°W, 1008 m a.s.l., soil samples, 9.VII.2016, C.A.F. Souza (URM 7770).

Habitat—Different soil types (Schipper 1976, Domsch & al. 1980, Mousavi & al. 2018), cattle, goat, and sheep dung (Souza & al. 2017), plants including fruits, such as *Capsicum annuum* and *Triticum aestivum* (Walther & al. 2013), yogurt (Snyder & al. 2016), commercial honey, fermenting rice, and causing mucormycosis in humans (Walther & al. 2013).

Geographic distribution—Australia, Belgium, Brazil, China, Finland, France, Germany, Greece, India, Japan, South Africa, Spain, the Netherlands, New Zealand, Turkey, Ukraine, Vietnam.

Comments—Recently, in a taxonomic review based on a polyphasic approach of *M. circinelloides* complex, Wagner & al. (2019) reclassified previously described forms into distinct species: *M. circinelloides*, *M. griseocyanus*, *M. jansseni*, and *M. lusitanicus*. Our isolate corresponds well to the morphological characters described and illustrated by Van Tieghem (1875) and Schipper (1976). This is the first report of *M. circinelloides* in the Brazilian upland forest.

Mucor griseocyanus Hagem, Skr. Videnskr.-Selsk. Christiania, Kl. I, Math.-Natur. 1907(7): 28 (1908) Fig. 2a–d

Colony: initially white to yellowish gray, then becoming dark gray, reverse yellowish, colonizing the entire Petri dish (9 cm diam., 0.5–1.5 cm high) in 5 days, at 25°C, on MEA. Sporangiophores hyaline to light gray, sympodially branched, with long or short branches; short branches often recurved, 6–10(–15) µm diam., with incrusted walls. Sporangia at first yellowish then becoming brown to brownish dark, globose, 20–65(–75) µm diam., with smooth or slightly incrusted and deliquescent wall, leaving a small but evident collar. Columellae grey to brownish grey, obovoid in larger sporangia, 25–60(–65) × 20–55 µm, and globose in the smallest ones, 20–45(–65) µm diam., smooth-walled. Sporangiospores hyaline, ellipsoid to broadly ellipsoid, 4–10 × 3.5–6.5 µm, globose to subglobose, 3.5–8 µm diam., smooth-walled. Zygosporangia not observed.

Specimen examined—**BRAZIL, Pernambuco, Brejo da Madre de Deus**, brejo da Serra do Bituri, 8.1833°S 36.4000°W, 1008 m a.s.l., soil samples, 9.VII.2016, C.A.F. Souza (URM 7771).

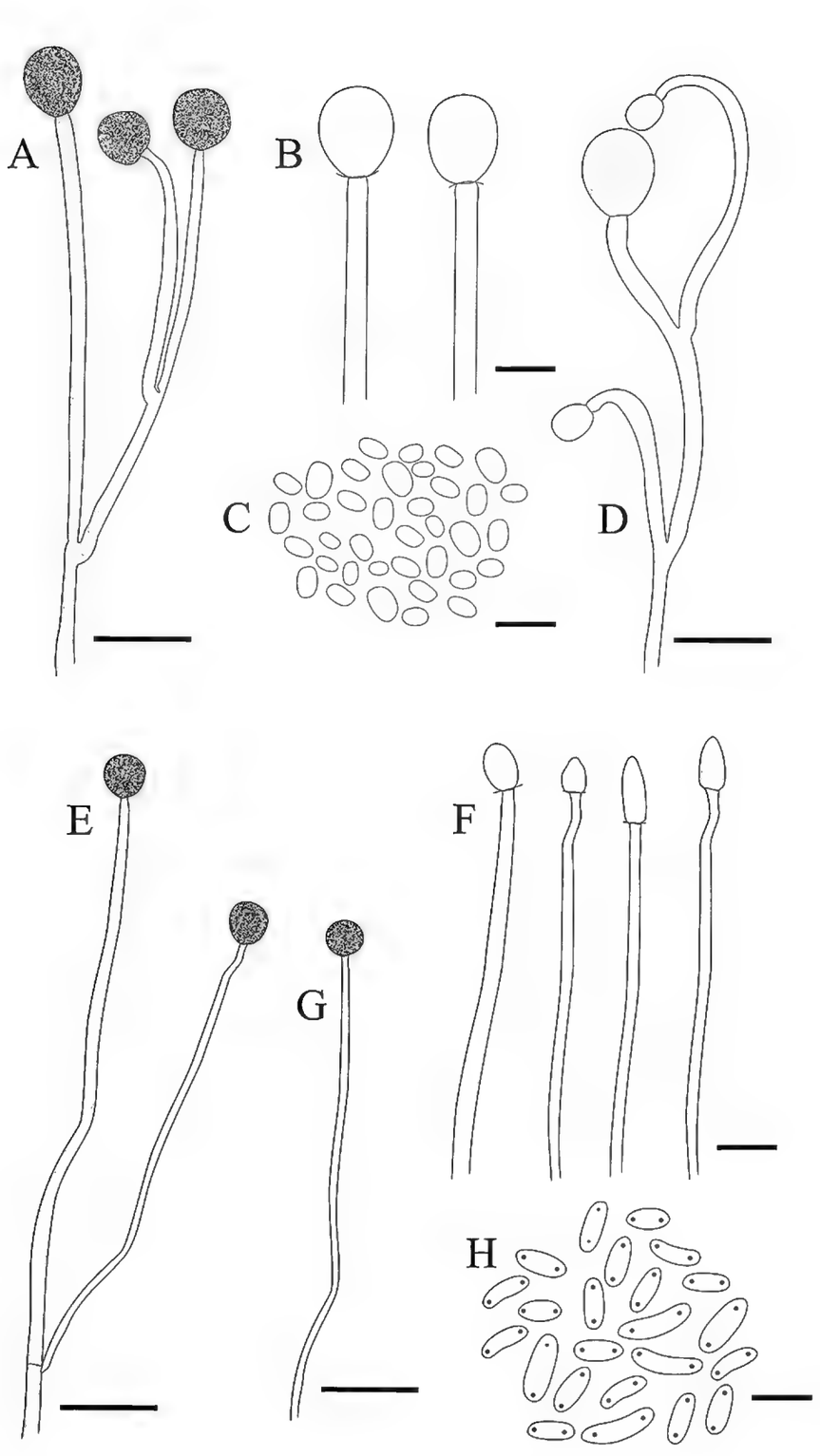

FIG. 2. ***Mucor griseocyanus*** (URM 7771): A. Sympodially branched sporangiophore with sporangia; B. Unbranched sporangiophores with columellae; C. Ellipsoid to broadly ellipsoid sporangiospores; D. Sympodially branched sporangiophore with columellae. ***Mucor guilliermondii*** (URM 7868): E. Simple branched sporangiophore with sporangia; F. Unbranched sporangiophores with columellae; G. Unbranched sporangiophore with sporangium; H. Ellipsoid and cylindrical to reniform sporangiospores. Scale bars = 20 µm.

Habitat—Forest soil, leaf litter, *Zea mays*, milk powder, canned strawberries (Schipper 1976), and excrements of cattle, goat, and sheep (Souza & al. 2017).

Geographic distribution—Brazil, Germany, India, Norway, South Africa, the Netherlands.

Comments—*Mucor griseocyanus*, previously described as a forma of the *M. circinelloides* complex (Schipper 1976) but recently reclassified by Wagner & al. (2019), is characterized by the production of globose sporangia ≤60 µm diam., sympodially branched sporangiophores, and ellipsoid sporangiospores. The characters of our isolate URM 7771 are similar to those described by Schipper (1976) except for its larger sporangial and columellar diameters. Schipper (1976) also noted such variations (≤60 µm diam. in the sporangia and ≤38 × 55 µm in the columellae). This is the first record of *M. griseocyanus* in the Brazilian upland forest.

Mucor guilliermondii Nadson & Philippov,
Rev. Gén. Bot. 37: 450 (1925) Fig. 2e–h

Colony white to slightly light gray, reverse yellowish, low and exhibiting slow growth (6 cm diam., ≤3 mm high) after 6 days, at 25°C frequently recurved, rarely presenting lateral branches, smooth-walled. Sporangia hyaline to yellowish, globose or subglobose to slightly depressed, 14–60 µm diam., smooth-walled, deliquescent, with vitreous aspect. Columellae hyaline, elongated-conical, infrequently subglobose and ellipsoidal, 15–30 × 5.5–14.5 µm, with slightly incrusted wall; a small collar may occur. Sporangiospores hyaline, ellipsoid and cylindrical to reniform, some irregular in shape, 3.5–8 × 2–4.5 µm, with one or more droplets at each end, smooth-walled. Chlamydospores globose to subglobose, cylindrical, and doliiform. Zygosporangia not observed.

Specimen examined—**BRAZIL, Pernambuco, Brejo da Madre de Deus**, brejo da Serra do Bituri, 8.1833°S 36.4000°W, 1008 m a.s.l., soil samples, 9.VIII.2016, C.A.F. Souza (URM 7868).

Habitat—Soil (Schipper 1978, Nadson & Philippov 1925) and excrements of tapir (*Tapirus terrestris*; Santiago & al. 2008).

Geographic distribution—Belgium, Brazil, France, Malaysia, Russia.

Comments—The characteristics of the *M. guilliermondii* strain URM 7868 are closely similar to the descriptions of Nadson & Philippov (1925) and Schipper (1978). Moreover, the URM 7868 characters correspond well to the description and illustration of Santiago & al. (2008), who isolated this species from tapir dung in an Atlantic Forest area in Recife, Pernambuco, Brazil, except for sporangiophore width, which was slightly smaller (≤6 µm diam.)

than those described in our study. Our isolate represents the first record of *M. guilliermondii* in the soil of the Brazilian upland forest.

Mucor hiemalis Wehmer, Ann. Mycol. 1(1): 39 (1903) FIG. 3A–E

COLONY initially white becoming light yellow, reverse yellowish, exhibiting good growth (9 cm diam., ≤1.5 cm high) after 4 days, at 25°C, on MEA. SPORANGIOPHORES hyaline, with or without yellowish contents, simple, monopodially or slightly sympodially (not frequent) branched with long branches, 8–17 µm diam., smooth-walled. SPORANGIA firstly hyaline to yellowish then turning dark yellow, globose to slightly depressed, 20–70(–80) µm diam., wall smooth and deliquescent. COLUMELLAE hyaline, ellipsoid with truncate base, globose when young, 15–40(–50) × 20–45 µm, hyaline to grayish, smooth-walled. SPORANGIOSPORES hyaline, ellipsoid, some flattened on one side, 2.5–8.5 × 2–5.5(–7.5) µm. OIDIA globose to subglobose and doliiform. CHLAMYDOSPORES present in the aerial mycelium. ZYGOSPORANGIA not observed.

SPECIMEN EXAMINED—**BRAZIL, PERNAMBUCO, Brejo da Madre de Deus**, brejo da Serra do Bituri, 8.1833°S 36.4000°W, 1008 m a.s.l., soil samples, 9.VIII.2016, C.A.F. Souza (URM 7881).

HABITAT—Different soil types (Schipper 1976; Trufem 1978, 1981a; Lima & al. 2016, 2018a; Anand & al. 2018), excrement of cattle, goat, and sheep (Souza & al. 2017), water samples (Alananbeh & al. 2017), *Picea abies* litter (Haňáčková & al. 2015), fresh biofilms from submerged rocks (Hoque & Fritscher 2017), commercial cheese (Ando & al. 2012), processed products derived from maize (e.g., maize flour, corn meal, cooked cornflakes; Santiago & Souza-Motta 2008), humans (Abirami 2019), endophytic in tuberous rhizome of *Curculigo orchioides* (Gaikwad & al. 2017) causing the disease *Miscanthus* rhizome rot (Beccari & al. 2010), and in mandarin fruit (Satio & al. 2016).

GEOGRAPHIC DISTRIBUTION—Australia, Austria, Bolivia, Brazil, Canada, Colombia, China, Denmark, Estonia, France, Germany, India, Japan, Malaysia, New Zealand, Nigeria, Northern Ireland, Norway, Russia, South Africa, Spain, Sweden, Switzerland, Ukraine, the Netherlands, United Kingdom, United States.

COMMENTS—*Mucor hiemalis* has a wide distribution in Brazilian ecosystems, being reported in the Atlantic Forest, Caatinga, and Cerrado domains (Schoenlein-Crusius & al. 2006, Souza & al. 2017, Lima & al. 2018b). URM 7881 shows a close similarity to the descriptions of Schipper (1973) and Lima

& al. (2018b), although differences in columellar size were observed between our isolate and those reported by Schipper (1973; ≤38 × 30 µm) and Lima & al. (2018b; ≤40 × 30 µm). This is the first report of *M. hiemalis* in the Brazilian upland forest.

Mucor inaequisporus Dade, Trans. Br. Mycol. Soc. 21(1–2): 25 (1937) FIG. 3F–I

COLONY intensely yellow, reverse yellow, mostly at the point of inoculum, exhibiting rapid growth (9 cm diam., ≤10 mm high) after 3 days, at 25°C, on MEA. SPORANGIOPHORES brownish, 9–30 µm diam., simple or with long and short sympodial branches (3–10 times), mostly in older colonies, erect, undulating, slightly curved, exhibiting one or several randomly spaced septa, with or without yellowish contents. SPORANGIA initially yellow, then becoming brown, globose and subglobose to slightly depressed, 70–130(–180) × 60–120 µm diam.; sporangial wall mostly deliquescent, but persistent in the smaller sporangia. COLUMELLAE hyaline to brownish yellow, varied in shape, often pyriform, conical or oblong, ellipsoid, obovoid and subglobose, 60–100 × 45–80(–120) µm, smooth-walled; collar commonly observed. SPORANGIOSPORES variable in shape and size, hyaline, with granular contents, mostly ellipsoid, sometimes flattened at one side, 5–15 × 3.5–10 µm, globose and subglobose, 8–15 µm diam., some irregular in shape, 25 × 15 µm. RHIZOIDS present, short to long, and poorly branched. CHLAMYDOSPORES and ZYGOSPORANGIA not observed.

SPECIMEN EXAMINED—**BRAZIL, PERNAMBUCO, Taquaritinga do Norte**, Brejo de Taquaritinga do Norte, 7.9078°S 36.0403°W, 1056 m a.s.l., soil samples, 5.X.2016, C.A.F. Souza (URM 7871).

HABITAT—Isolated from fruits of *Artocarpus glaucus, Bouea macrophylla, Diospyros kaki, Flacourtia inermis, Musa ×paradisiaca, Spondias mombin, Syzygium cumini,* and *Theobroma cacao* (Dade 1937, Boedijn 1959, Santiago & al. 2013b) and from rhizosphere of root-knot nematode host plants (Zangeneh & al. 2007).

GEOGRAPHIC DISTRIBUTION—Brazil, Ghana, Indonesia, Iran, Malaysia.

COMMENTS—*Mucor inaequisporus* was first described by Dade (1937) from *S. mombin* fruits in Aburi, Ghana. This species is characterized by the highly variable form and size of columellae and sporangiospores (Schipper 1978). Our isolate shows similarities to those described by Schipper (1978) and Santiago & al. (2013b), although the sporangiophores with irregular swellings as described by Santiago & al. (2013b) were not observed in URM 7871. In addition, the columellae described by Dade (1937) and Schipper (1978) are

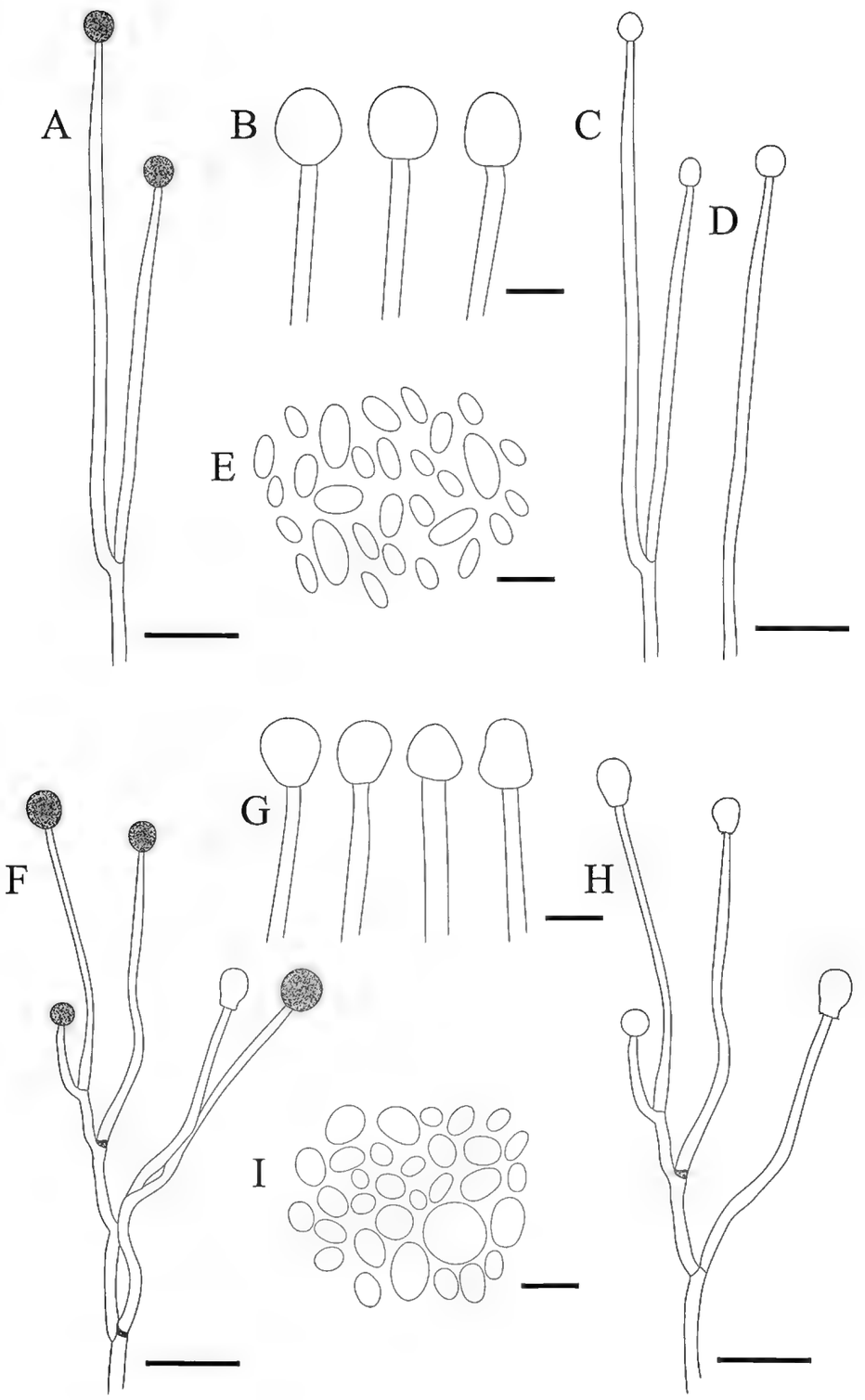

FIG. 3. ***Mucor hiemalis*** (URM 7881): A. Simple branched sporangiophore with sporangia; B. Unbranched sporangiophores with columellae; C. Simple branched sporangiophore with columellae; D. Unbranched sporangiophore with columella; E. Sporangiospores ellipsoid, some flattened at one side. ***Mucor inaequisporus*** (URM 7871): F. Sympodially branched sporangiophore with sporangia and columella; G. Unbranched sporangiophore with columellae; H. Sympodially branched sporangiophore with columellae; I. Sporangiospores variable in shape and size. Scale bars = 20 μm.

smaller (≤83 µm diam.) than those of URM 7871. According to Schipper (1978), different strains of *M. inaequisporus* can exhibit morphophysiological variations. This is the first report of *M. inaequisporus* in the Brazilian upland forest.

Mucor indicus Lendn.,
Bull. Soc. Bot. Genève, sér. 2, 21: 258 (1930 ["1929"]) Fig. 4a–d

Colony initially white, becoming deep yellowish, with yellowish reverse, colonizing the entire Petri dish (9 cm diam., 1 cm high) in 4 days, at 28°C, on MEA. Sporangiophores hyaline to yellowish, erect, sympodially branched, with long branches, rarely circinate, 5–12(–15) µm diam., smooth-walled. Sporangia brownish, globose to subglobose, 32–45(–50) µm diam., with diffluent wall. Columellae grayish or yellowish brown, globose 30–50 µm diam., subglobose, 27–30 × 42–45(–50) µm or applanate, 20–22 × 27–30(–32) µm, smooth-walled; collar small and infrequent. Sporangiospores hyaline, smooth-walled, often ellipsoid, 4–6 × 3–6 µm and subglobose, 4–6(–7.5) µm diam. Chlamydospores and Oidia present. Zygosporangia not observed.

Specimen examined—**BRAZIL, Pernambuco, Taquaritinga do Norte**, Brejo de Taquaritinga do Norte, 7.9078°S 36.0403°W, 1056 m a.s.l, soil samples, 5.X.2016, C.A.F. Souza (URM 7854).

Habitat—Different soil types (Lendner 1930, Szwedek-Trzaska & Glowacka 2011), fermented products of grains like ragi (Lee & Fujio 1999), goat dung (Souza & al. 2016), and humans (Álvarez & al. 2011).

Geographic distribution—Brazil, Germany, India, Indonesia, Poland, Qatar, South Africa, Spain, Switzerland, United States, Vietnam.

Comments—The morphological characteristics of *M. indicus* strain URM 7854 agree with the descriptions by Schipper (1978) and Souza & al. (2016). Specimens of *M. indicus* are characterized by the production of sporangiophores repeatedly sympodially branched, with long branches and sporangiospores often ellipsoid and subglobose. The ellipsoid sporangiospores of URM 7854 were larger than those reported by Schipper (1978: ≤5.7 × 4.4 µm). This is the first report of *M. indicus* in the Brazilian upland forest.

Mucor irregularis Stchigel, Cano, Guarro & E. Álvarez,
Medical Mycol. 49(1): 71 (2011) Fig. 4e–h

Colony initially white then turning yellowish to cream-colored, reverse yellowish, with cottony aspect, colonizing the entire Petri dish (9 cm diam., 1 cm high) after 4 days, at 25°C, on MEA. Sporangiophores hyaline,

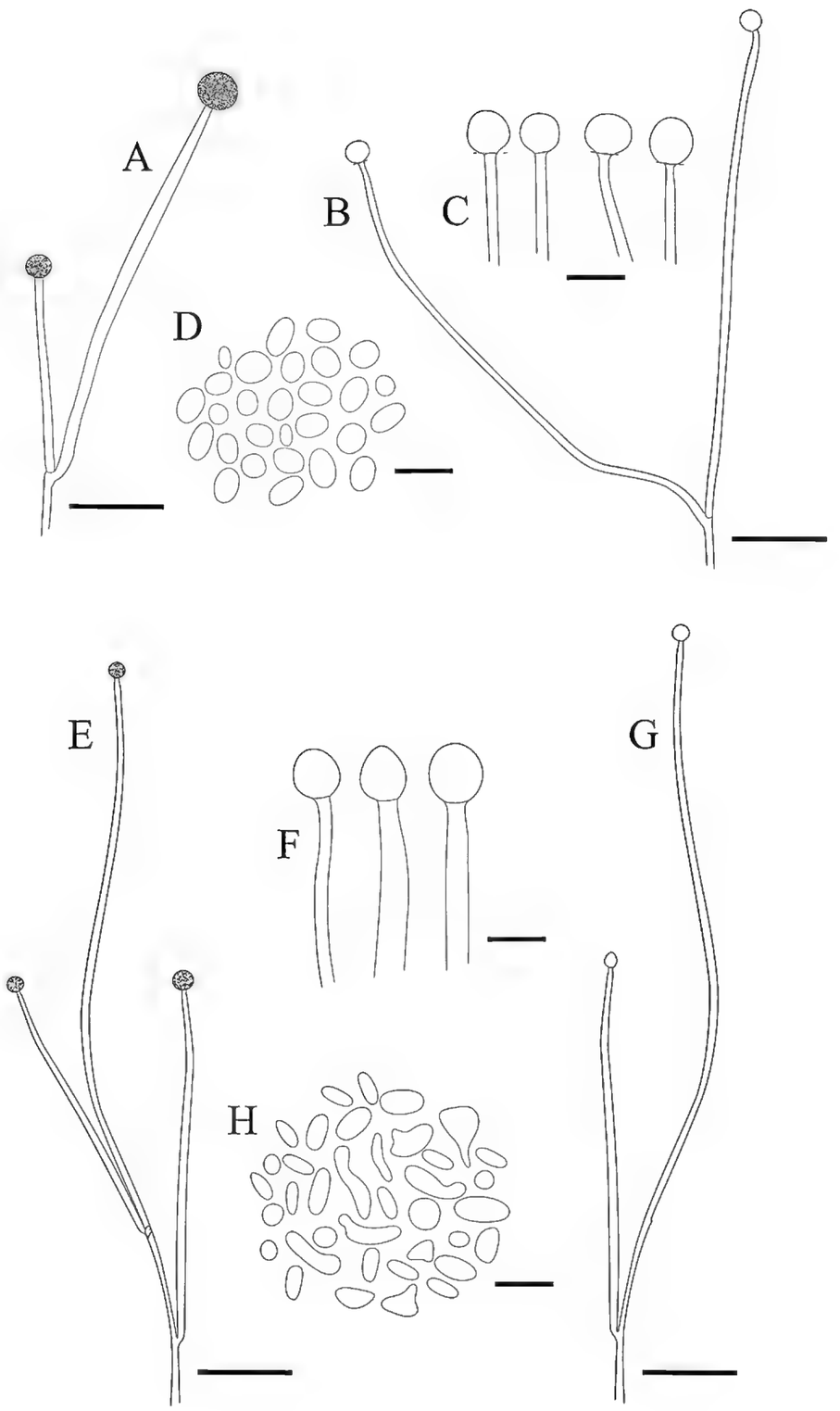

Fig. 4. ***Mucor indicus*** (URM 7854): A. Simple branched sporangiophore with sporangia; B. Simple branched sporangiophore with columellae; C. Unbranched sporangiophores with columellae; D. Ellipsoid and subglobose sporangiospores. ***Mucor irregularis*** (URM 7773): E. Sympodially branched sporangiophore with sporangia; F. Unbranched sporangiophores with columellae; G. Simple branched sporangiophore with columellae; H. Sporangiospores variable in shape and size. Scale bars = 20 μm.

with or without yellowish contents, erect, sympodially and monopodially branched, arising from aerial hyphae 5–15.5(–25) µm diam., smooth-walled. Sporangia grayish brown, globose to subglobose, 30–40(–50) µm diam., with diffluent wall. Columellae brownish, globose, 12–30 µm diam., ellipsoid to cylindrical, 30–35 × 20–30 µm and rarely conical, 25–40 × 20–35 µm, some variable in shape, smooth-walled; collar small and little evident. Sporangiospores hyaline, mostly ellipsoid 2.5–10 × 2–5(–10) µm, subspherical to ovoid 4–9.5 × 2.5–7 µm, or globose, 2.5–10 µm diam., some irregularly shaped ≤12 µm diam., smooth-walled. Rhizoids hyaline, slightly branched. Chlamydospores and oidia observed. Zygosporangia not observed.

Specimen examined—**BRAZIL, Pernambuco, Taquaritinga do Norte**, Brejo de Taquaritinga do Norte, 7.9078°S 36.0403°W, 1056 m a.s.l., soil samples, 5.X.2016, C.A.F. Souza (URM 7773).

Habitat—Humans, causing human primary cutaneous mucormycosis (Zheng & Chen 1991, Lu & al. 2013), soldier fly larvae gut (Nguyen & al. 2016), and soil (Lima & al. 2018d). One specimen has been reported as endophytic in the roots of *Sorghum bicolor* (Lima & al. 2018d).

Geographic distribution—Australia, Brazil, China, Japan, India, Nigeria, South Korea, United States.

Comments—*Mucor irregularis* was first isolated and described as *Rhizomucor variabilis* R.Y. Zheng & G.Q. Chen from lesions of a patient, causing cutaneous or subcutaneous clinical infections (Zheng & Chen 1991). The holotype was described as producing variable and irregular shaped columellae. Although our isolate corresponded well with the description of the holotype, we did not observe any variable and irregular columellae. Lima & al. (2018d), who isolated *M. irregularis* from soil in Brazil, also reported no irregularly shaped columellae.

Mucor jansseni Lendn.,
Bull. Herb. Boissier, sér. 2, 7: 251 (1907), [as '*janseni*'] Fig. 5a–d

Colony initially white to light grayish then turning dark gray, growing in the entire Petri dish (9 cm diam., 0.5–1.5 cm high) in 5 days, reverse yellowish gray, at 25°C, on MEA. Sporangiophores hyaline to grayish, short branches repeatedly sympodially branched, rarely monopodially branched later, apical branches often short and circinate, 7–10(–20) µm diam., with or without yellowish contents; wall slightly incrusted. Sporangia initially yellowish then dark brownish, globose and subglobose 20–80(–90) µm diam.,

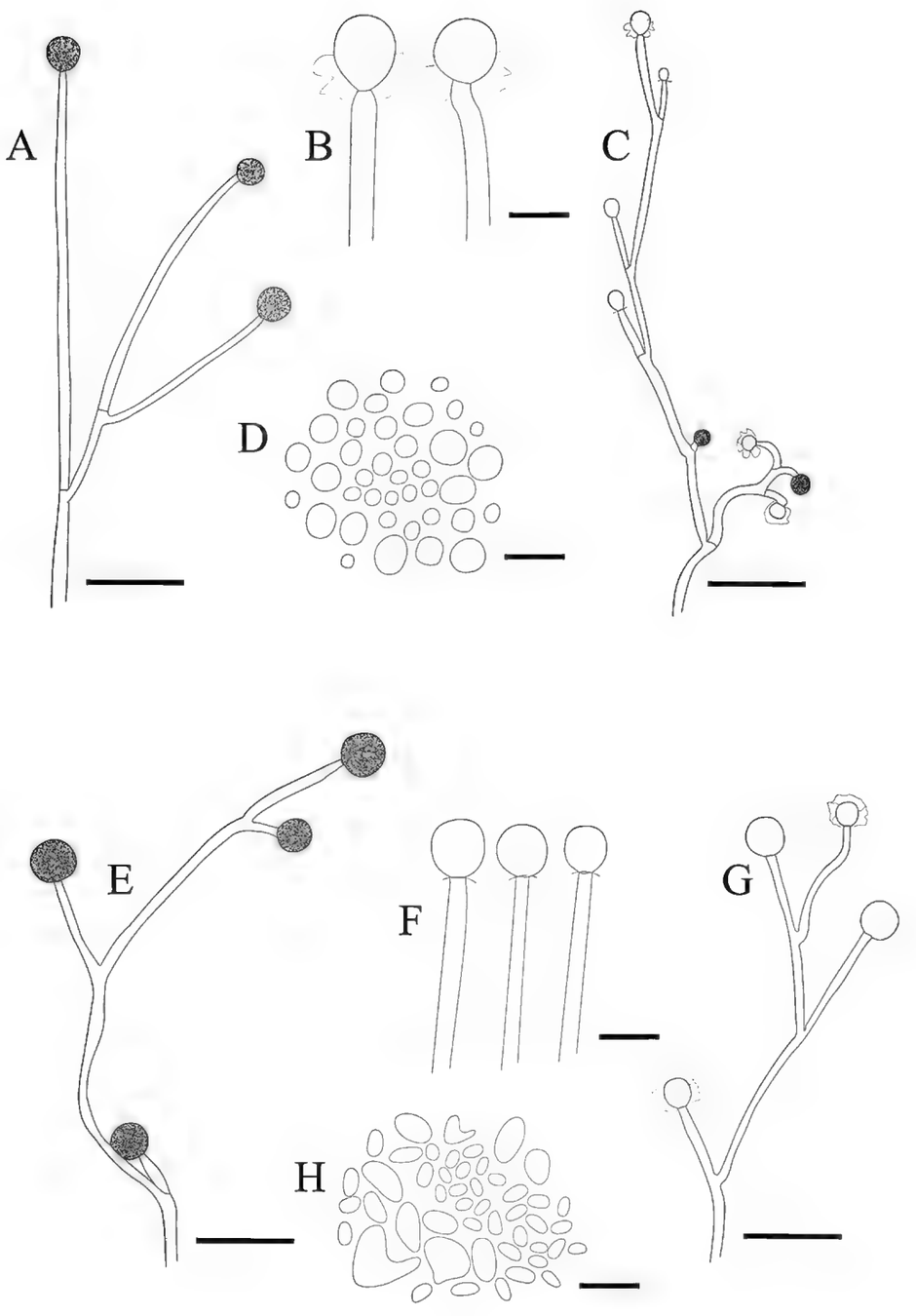

FIG. 5. ***Mucor jansseni*** (URM 7880): A. Sympodially branched sporangiophore with sporangia; B. Unbranched sporangiophore with columellae; C. Repeatedly sympodially branched sporangiophore with columellae and sporangia; D. Globose to subglobose sporangiospores. ***Mucor lusitanicus*** (URM 7853): E. Sympodially branched sporangiophore with sporangia; F. Unbranched sporangiophores with columellae; G. Sympodially branched sporangiophore with columellae; H. Sporangiospores variable in shape and size. Scale bars = 20 µm.

with incrusted wall, which is persistent in the small sporangia. Columellae grayish, obovoid in the larger sporangia, 25–65 × 20–50 µm, and globose in the smaller ones, 10–55(–65) µm diam., smooth-walled; collar common. Sporangiospores hyaline, globose to subglobose 3–10 µm diam.; smooth-walled. Zygosporangia not observed.

Specimen examined—**BRAZIL, Pernambuco, Brejo da Madre de Deus**, brejo da Serra do Bituri, 8.1833°S 36.4000°W, 1008 m a.s.l., soil samples, 5.VII.2016, C.A.F. Souza (URM 7880).

Habitat—Forest and grassland soils (Schipper 1976), excrements of cattle, goats, and sheep (Souza & al. 2017), the insect *Carausius morosus* (Schipper & al. 1975), and humans (Walther & al. 2013).

Geographic distribution—Brazil, China, France, India, Malaysia, Russia, South Africa, South Korea, the Netherlands, Vietnam.

Comments—*Mucor jansseni* was previously described as a forma in the *M. circinelloides* complex, recently reclassified by Wagner & al. (2019). The morphological characteristics of URM 7880 show close similarity to the description of Schipper (1976) (as *M. circinelloides* f. *jansseni*). Sporangia and columellae of URM 7880 were larger than those reported by Schipper (1976: sporangia ≤80 µm diam.; columellae ≤35 × 33 µm).

Mucor lusitanicus Bruderl.,
Bull. Soc. Bot. Genève, sér. 8: 276 (1916) Fig. 5e–h

Colony grayish yellow to brownish, reverse yellow, colonizing the entire Petri dish (9 cm diam., ≤1 cm high) after 5 days at 25°C on MEA. Sporangiophores hyaline to slightly pale gray, with or without yellowish contents, 6–20 µm diam., repeatedly sympodially branched, wall slightly incrusted. Circinate branches are uncommon. Sporangia initially yellowish then becoming brownish, globose to subglobose, 18–75(–85) µm diam., sporangial wall deliquescent. Columellae grayish, globose and subglobose, 15–55(–75) µm diam., smooth-walled; collar common. Sporangiospores hyaline, variable in size and shape, ellipsoid, 3–7 × 2.5–3.5 µm, irregular, 4–14 × 3–12 µm, rarely globose to subglobose, 2.5–5 µm diam., smooth-walled. Zygosporangia not observed.

Specimen examined—**BRAZIL, Pernambuco, Taquaritinga do Norte**, Brejo de Taquaritinga do Norte, 7.9078°S 36.0403°W, 1056 m a.s.l., soil samples, 4.IX.2016, C.A.F. Souza (URM 7853).

Habitat—Isolated from forest soil and *Zea mays* (Schipper 1976, Walther & al. 2013), fermented soybeans (sufu starter: Schipper 1976; meju: Hong & al.

2012), excrements of cattle and sheep (Souza & al. 2017), humans (Álvarez & al. 2011).

Geographic distribution—Brazil, China, France, Mexico, Portugal, Russia, South Africa, United States.

Comments—*Mucor lusitanicus* was previously described as a forma of the *M. circinelloides* complex, recently reclassified by Wagner & al. (2019). This species is characterized by producing variably sized and shaped sporangiospores, with some irregularity in shape. The morphological characteristics of *M. lusitanicus* of URM 7853 agree with those described by description of Schipper (1976) except that its irregular sporangiospores are smaller than those reported by Schipper (1976: 5.5 × 17.6 µm) and its ellipsoid sporangiospores are larger than those observed by Alves & al. (2002: ≤2.5 × 3.1 µm).

Mucor luteus Linnem. ex Wrzosek, Mycotaxon 111: 81 (2010) Fig. 6a–d

Colony with cottony aspect, warm buff-colored, reverse yellowish, exhibiting good growth (9 cm diam., ≤1.5 cm high) after 4 days at 25°C on MEA. Sporangiophores hyaline, with or without yellowish contents, 5–16 µm diam., simple or slightly branched sympodially, smooth-walled. Sporangia hyaline to yellowish, globose, 15–70(–90) µm diam., wall smooth and deliquescent. Columellae hyaline to grayish, globose, 12.5–60 µm diam., smooth-walled; collar often evident. Sporangiospores hyaline, narrow ellipsoidal to fusiform, 2.5–10 × 1.5–5 µm, smooth-walled. Chlamydospores and Zygosporangia not observed.

Specimen examined—**BRAZIL, Pernambuco, Brejo da Madre de Deus**, brejo da Serra do Bituri, 8.1833°S 36.4000°W, 1008 m a.s.l., soil samples, 5.IX.2016, C.A.F. Souza (URM 7772).

Habitat—Isolated from different soil types (Santiago & al. 2013a, Sarsaiya & al. 2017), rhizoplane of grapevine *Vitis labrusca* (Lima & al. 2014), excrements of cattle, goat, and sheep (Souza & al. 2017), water samples (Zvereva & al. 2012), oral and cloacal openings of free-living four-lined snakes *Elaphe quatuorlineata* (Lukač & al. 2017), and as endophytes of chili crops (*Capsicum annuum* L.; Trizelia & al. 2017).

Geographic distribution—Australia, Brazil, Germany, India, Japan, Montenegro, Nigeria, Russia, South Africa, Sweden, and Poland.

Comments—The morphological characteristics of *M. luteus* described here are closely similar to the description in Schipper (1973). Sporangiospores narrow

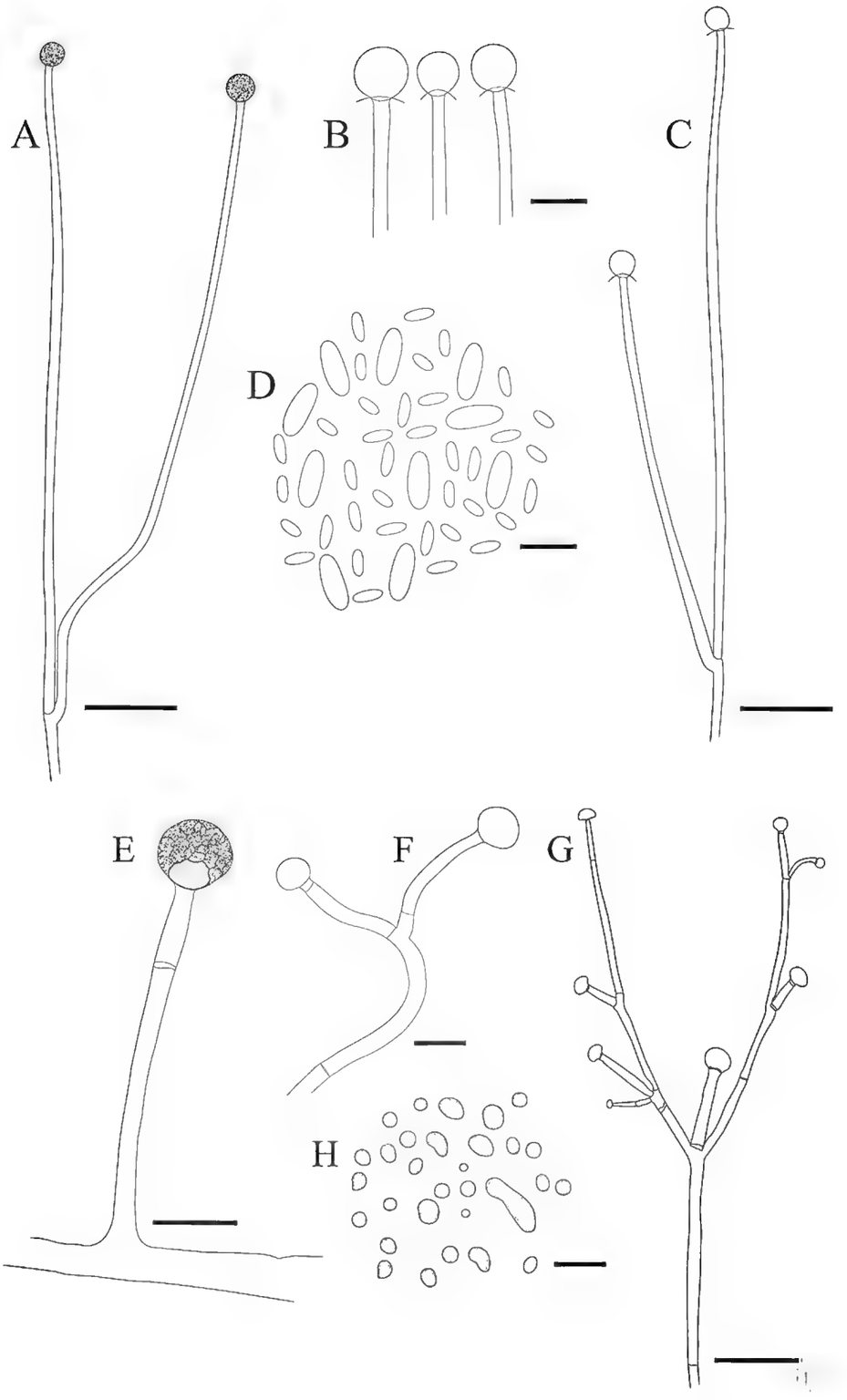

Fig. 6. ***Mucor luteus*** (URM 7772): A. Simple branched sporangiophore with sporangia; B. Unbranched sporangiophores with columellae; C. Simple branched sporangiophore with columellae; D. Narrow ellipsoidal to fusiform sporangiospores. ***Mucor septatiphorus*** (URM 7364 - holotype): E. Unbranched septate sporangiophore with sporangium; F. Branched multiseptate sporangiophore with columellae; G. Sympodially branched multiseptate sporangiophore with columellae; H. Sporangiospores variable in shape and size. Scale bars = 20 μm.

ellipsoidal to fusiform correspond to those described by this author, although small differences in the maximum sizes of sporangia and columellae were observed in our strain. Schipper (1973) reported sporangia ≤70 µm diam. as well as columellae ≤45 × 47 µm, both smaller than those of URM 7772.

Mucor septatiphorus C.A.F. Souza, T.R. Cordeiro & A.L. Santiago, **nom. nov.**

FIG. 6E–H

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≡ *Mucor septatus* C.A.F. Souza, T.R. Cordeiro & A.L. Santiago, Phytotaxa 351(1): 56 (2018), [as "*septatum*"], nom. illeg., non Bezold 1889.

SPECIMEN EXAMINED—**BRAZIL, PERNAMBUCO, Brejo da Madre de Deus**, brejo da Serra do Bituri, 8.1833°S 36.4000°W, 1008 m a.s.l., soil samples, 5.IX.2016, C.A.F. Souza (URM 7364, holotype).

HABITAT—Isolated from the soil (Souza & al. 2018).

GEOGRAPHIC DISTRIBUTION—Brazil.

COMMENTS—This species is characterized by the concomitant presence of bent, circinate, simple or branched (most heavily branched) sporangiophores with one to several septa. The description and illustration of the holotype (URM 7364) are provided by Souza & al. (2018).

Mucor souzae C.A.F. Souza, D.X. Lima & A.L. Santiago, Persoonia 40: 307 (2018) FIG. 7A–D

SPECIMEN EXAMINED—**BRAZIL PERNAMBUCO, Triunfo**, Brejo do Sítio Carro Quebrado, 7.8748°S 38.1034°W, 913 m a.s.l., soil samples, 6.XI.2016, C.A.F. Souza (URM 7553, holotype).

HABITAT—Isolated from the soil (Crous & al. 2018).

GEOGRAPHIC DISTRIBUTION—Brazil.

COMMENTS—*Mucor souzae* is mainly characterized by producing sporangiophores from aerial mycelia, simple or repeatedly sympodially branched, with long or short branches as well as variably shaped and sized sporangiospores. One or two septa sometimes form below the sporangia. The description and illustration of the holotype (URM 7553) are available in Crous & al. (2018).

Mucor variicolumellatus L. Wagner & Walther. Persoonia 44: 92 (2019) FIG. 7E–H

SPECIMEN EXAMINED—**BRAZIL, PERNAMBUCO, Taquaritinga do Norte**, Brejo de Taquaritinga do Norte, 7.9078°S 36.0403°W, 1056 m a.s.l., soil samples, 5.X.2016, C.A.F. Souza (URM 7769).

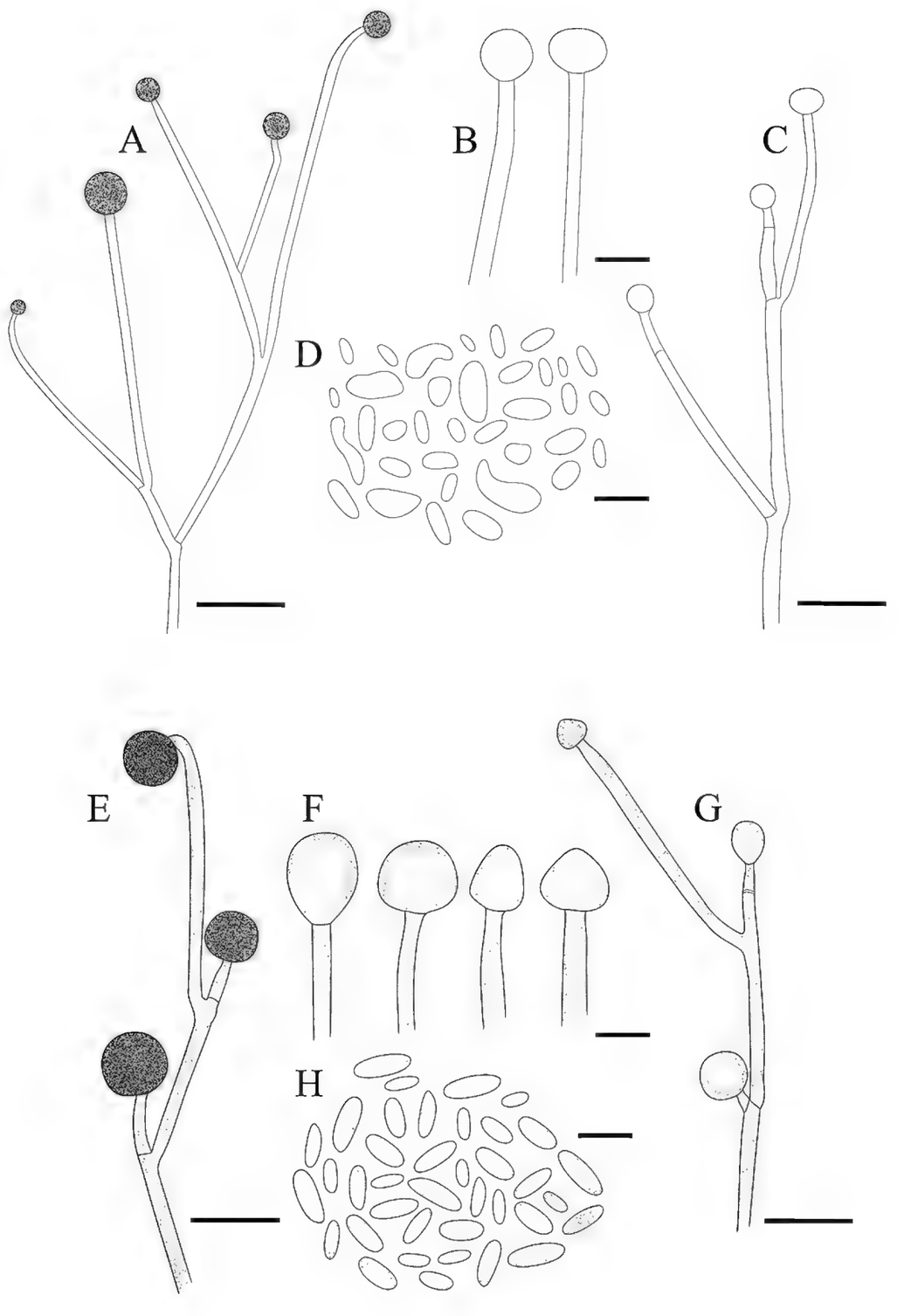

Fig. 7. ***Mucor souzae*** (URM 7553, holotype): A. Sympodially branched sporangiophore with sporangia; B. Unbranched sporangiophores with columellae; C. Sympodially branched sporangiophore with columellae; D. Sporangiospores variable in shape and size. ***Mucor variicolumellatus*** (URM 7769): E. Sympodially branched sporangiophore with sporangia; F. Unbranched sporangiophores with columellae; G. Sympodially branched sporangiophore with columellae; H. Sporangiospores ellipsoidal, variable in size. Scale bars = 20 μm.

Habitat—Isolated from *Tremella*, maize meal, humans (Álvarez & al. 2011, as *M. fragilis*), and soil (Souza & al. 2020).

Geographic distribution—Brazil, Germany, Malawi, United States.

Comments—*Mucor variicolumellatus* was proposed by Wagner & al. (2019). It was isolated from humans (Álvarez & al. 2011, as *M. fragilis*) and maize meal from Malawi. This species resembles *M. lusitanicus,* except that only *M. variicolumellatus* produces obovoid, ovoid, and strawberry-shaped columellae. The morphological characteristics of *M. variicolumellatus* illustrated here show a close similarity to the description given by Wagner & al. (2019). A detailed description and illustration of URM 7769 are available in Souza & al. (2020).

Discussion

Studies on *Mucoromycota* (including *Mucor* spp.) in Brazilian ecosystems are fragmented. Around 110 taxa of this phylum were registered in Brazil, mostly concentrated in the Atlantic Forest (66 taxa), Caatinga (27), and Cerrado (16) domains (Lima & al. 2016, 2018b; Souza & al. 2018; Flora e Funga do Brasil 2022). To date, only seven *Mucor* species have been reported in the Brazilian upland forests, including three new species isolated from the soil in this ecosystem (Lima & al. 2018c, Souza & al. 2018, Crous & al. 2018).

Hawksworth & Lücking (2017) estimated that there are between 2.2 to 3.8 million species of existing fungi; nevertheless, currently, only around 120,000 are known. Thus, it is probable that the species richness in tropical areas is underestimated, and new studies may reveal a greater richness of *Mucoromycota* in these areas. The authors highlighted the number of undescribed species waiting to be discovered in biodiversity hot spots in the tropics.

In our study, 14 *Mucor* species were isolated from upland forests, of which twelve are presented here as new records for this poorly studied ecosystem. Brazilian upland forest areas have undergone a continuous and systematic degradation process in an unsustainable and intense manner (Medeiros & Cestaro 2019), with serious impacts on the quality of original ecosystems (Freire & al. 2018). Therefore, studies on the knowledge of fungi diversity in this ecosystem are crucial to generate data for the ecological maintenance of these areas and to guide conservation efforts for these fungi.

The results presented here underscore the richness of *Mucor* species in three upland forest fragments and the data allow for expanding the taxonomic knowledge and the geographical distribution of these fungi. The

isolated specimens were deposited at the URM culture collection of the Federal University of Pernambuco, for further tests in biochemical studies on the evaluation of enzyme production, such as amylases, proteases, cellulases, and tannases for industrial application.

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Texas microfungi: on the taxonomic placement of *Flosculomyces floridaensis* in *Zygosporiaceae*

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Abstract—The phylogenetic relationships and taxonomic placement of the anamorph *Flosculomyces floridaensis* are explored for the first time based on a strain isolated from a culturable air sample collected indoors in Texas, USA. Unpublished sequences obtained online from six well-characterized strains isolated in Japan were also included. Phylogenetic analyses using DNA sequence data from two different nuclear ribosomal loci (ITS, LSU) suggest that the fungus is a member of *Xylariales* (*Sordariomycetes*) and forms a distinct monophyletic lineage within *Zygosporiaceae*. The genus is recognized as a phylogenetically well-circumscribed taxon in agreement with its peculiar and unique morphology. The monophyletic *Zygosporiaceae* is recovered as five distinct and well delimited lineages based on the disparate morphologies of their anamorphs whereas *Zygosporium* was resolved as paraphyletic within the family. *Flosculomyces floridaensis* has not previously been reported in the continental USA outside its type locality in Florida and is recorded here for the first time from Texas.

Key words—airborne, hyphomycetes, taxonomy

Introduction

Flosculomyces B. Sutton was introduced to accommodate a peculiar anamorph collected on dead leaves of *Podocarpus* sp. (*Podocarpaceae*) in subtropical Florida, U.S.A. (Sutton 1978). Its type species, *F. floridaensis* B. Sutton, is characterized by round, four-celled, lobed and cruciately septate conidia that are darkly pigmented in the center, paler toward the periphery, and horizontally flattened in lateral view. They emerge from

holoblastic, integrated, or discrete conidiogenous cells, usually ampulliform and constricted in the middle, their apices often collapsing and becoming cupulate after conidium detachment. They arise singly or disposed on lateral branches with one or two orders, usually in whorls of up to three at the apex of macronematous, mononematous conidiophores. A second species, *F. trilobatus* Onofri, was later described on dead leaves collected in Ivory Coast (Onofri 1984), with slightly smaller, three-celled conidia. The genus is considered *Ascomycota* incertae sedis (Wijayawardene & al. 2021) and its phylogenetic relationships are currently unknown. However, Tanaka & al. (2017) placed *F. floridaensis* in *Xylariales* based on BLAST searches of ITS sequence data obtained from a strain isolated in Japan.

The fungus apparently has a pantropical distribution (Mena & al. 2020) with records mainly in the Neotropics and the Asian Paleotropics. In the Neotropics, it has been recorded several times in Brazil on dead leaves of *Clusia nemorosa* G. Mey. (*Clusiaceae*) (Marques & al. 2007, Barbosa & al. 2009) and in Cuba on a branch of *Pandanus* sp. (*Pandanaceae*) (Arnold 1985), dead rachides of *Cocos nucifera* L. (*Arecaceae*) (Mercado & al. 2002), dead leaves of *Calophyllum antillanum* Britton, *C. calaba* L. (*Calophyllaceae*), and *Pimenta dioica* (L.) Merr. (*Myrtaceae*) (Camino & al. 2006), and petioles of dead leaves of *Roystonea regia* O.F. Cook (*Arecaceae*) (Mena & al. 2020). In the Paleotropics, Yokoyama & Ito (1989) first isolated the fungus on culture media from peduncle sheath of *Pandanus boninensis* Warb. and fallen leaves of *Calophyllum inophyllum* L. and *Lithocarpus edulis* Nakai (*Fagaceae*) in Japan. The resulting four strains are currently deposited in NBRC (http://www.nite.go.jp/en/nbrc/cultures/index.html). Other strains were obtained in Japan from leaves of *Pittosporum tobira* W.T. Aiton (*Pittosporaceae*) by Ono & Kobayashi (2005) and from leaves of *Arenga engleri* Becc. (*Arecaceae*) by Tanaka & al. (2017). These two strains are currently deposited in MAFF and accessible at the NARO GenBank database (https://www.gene.affrc.go.jp/databases_en.php). Additional records have been reported from Hong Kong on decaying leaves of *Pandanus furcatus* Roxb., the Philippines on decaying leaves of *Pandanus* sp. (Whitton & al. 2012), and India as an endophyte from fresh leaves and twigs of *Artocarpus* sp. (*Moraceae*) (Bhat 2010). There are also scattered records in Africa on leaves of *Pandanus* sp. in Mauritius (Dulymamode & al. 2001) and on dead leaves of *Drypetes aylmeri* Hutch. & Dalziel (*Putranjivaceae*) and *Didelotia idae* J. Léonard & al. (*Fabaceae*) in Ivory Coast (Rambelli & al. 2004). Matsushima (1989), on the other hand, reported the fungus on dead leaves of *Acacia aulacocarpa* A. Cunn. ex Benth.

(*Fabaceae*) in Australia. Frequently, airborne conidia of *F. floridaensis* are found in the atmosphere suggesting that wind plays an important role in their dispersal. Although originally described from Florida, the fungus has not been further reported in other locations across the continental USA.

During routine analyses of culturable air samples received in our laboratory for indoor air quality assessments, a colony of *F. floridaensis* was identified and recovered. In order to determine the phylogenetic relationships of the fungus and to infer its taxonomic placement within *Ascomycota*, DNA sequence data of two different nuclear ribosomal loci were obtained and analyzed. Results are presented here along with morphological and cultural studies of the recovered strain and couple of non-culturable airborne specimens. They serve to document the presence of the fungus in Texas.

Materials & methods

Isolation and morphological studies

The original colony was recovered from an indoor air sample collected on an agar plate using an Andersen sampler (Andersen 1958) after 7 days of incubation at 25°C. Single conidia were transferred aseptically to 2% Malt Extract Agar (MEA) and incubated following identical conditions. Colony features were observed after seven days with sporulation being monitored during subculturing. Microscopic slides were mounted in lacto-cotton blue and microphotographs were taken using an Olympus BX-45 compound microscope. A total of 50 measurements were made at 1000× magnification for each fungal structure. Minimum, maximum, 5th and 95th percentile values were calculated with outliers given in parentheses. Unfortunately, it was not possible to deposit a living culture due to persistent contamination following subculturing. However, a clean voucher specimen, in the form of a dried culture and semi-permanent slides, is deposited in the U.S. National Fungus Collections, Beltsville MD, USA (BPI). Non-culturable airborne conidia collected on glass slides inside Air-O-Cell sampling cassettes (Zefon International, Ocala, Florida, USA) were also studied following similar procedures and slide specimens were deposited as well in BPI. Fungal names throughout the text follow Index Fungorum (http://www.indexfungorum.org/) and Tropicos (https://tropicos.org/home) for host plant names. Herbaria acronyms follow Index Herbariorum (http://sweetgum.nybg.org/science/ih/) and culture collection acronyms follow the Culture Collections Information Worldwide of the WFCC-MIRCEN World Data Center for Microorganisms (http://www.wfcc.info/ccinfo/).

DNA extraction, PCR amplification, and sequencing

An isolate was grown on MEA for 14 days at 25°C and sent to a sequencing facility, Laragen, Inc. for Microbial Identification Service (http://www.laragen.com/laragen_microbial.php). Genomic DNA was extracted from fresh mycelium following the company's protocols and the complete internal transcribed spacer

Table 1. Strains and sequences included in the phylogenetic analysis. New sequences are highlighted in bold.

Taxon	Strain	GenBank ITS	GenBank LSU
Ascotricha chartarum	CBS 104.25	MH854797	MH866301
	CBS 110.52	MH856946	MH868472
	CBS 902.69	MH859477	MH871257
	HMCK-30	MK051122	MK051166
A. erinacea	CBS 116.31	MH855151	MH866600
	CBS 194.71^{T}	MH860063	MH871844
	CBS 407.87	KF893287	—
	CBS 535.73	KF893285	MH872482
	NBRC 32298^{T}	IF03229801*	IF03229801*
	NBRC 9841	IF00984101*	IF00984101*
A. funiculosa	CBS 124.80^{T}	MH861246	MH873018
	CBS 323.86	KU683762	KU683762
A. lusitanica	CBS 462.70^{T}	KF893289	MH877806
	FMR 17607	—	LR812705
A. microspora	NHES L1706^{T}	MF805818	—
A. pusilla	CBS 132.60	MH857921	MH869465
A. rugispora	NBRC 33167^{T}	LC146763	LC146763
Ascotricha sp.	GLMC 453	MT153622	MT156161
Astrocystis sublimbata	CBS 130006	MH865618	MH877041
Atrotorquata spartii	MFLUCC 13-0444	—	KP325443
Ciliosporella italica	MFLU 16-1114^{T}	MT177929	MT177956
Coniocessia anandra	IRAN 1468C^{T}	GU553338	GU553349
C. cruciformis	IRAN 1474C	GU553335	GU553346
C. maxima	IRAN 1602C	GU553332	GU553344
C. nodulisporioides	CBS 281.77	GU553342	AJ875224
Entoleuca mammata	CBS 235.34	—	MH866995
Flosculomyces floridaensis	BPI 919995	**MZ353014**	**MZ353015**
	MAFF 239738	—	—
	MAFF 243957	—	—
	NBRC 30653	IF03065301*	IF03065301*
	NBRC 30654	IF03065401*	IF03065401*
	NBRC 30655	IF03065501*	IF03065501*
	NBRC 30656	IF03065601*	IF03065601*
Guayaquilia cubensis	MUCL 39017	KC775733	KC775708
Hypocopra rostrata	NRRL 66178	KM067909	KM067909
Idriella lunata	CBS 204.56^{T}	KP859044	KP858981
Kretzschmaria deusta	CBS 723.69	—	MH871168

Microdochium majus	CBS 741.79	KP859001	KP858937
M. nivale	CBS 116205	KP859008	KP858944
Nemania serpens	CBS 241.65	—	MH870193
Neoidriella desertorum	CBS 985.72[T]	KP859048	KP858985
Paraxylaria rosacearum	TASM 6132[T]	MG828941	MG829050
Rosellinia aquila	ILLS 121141	—	MG845555
R. convexa	MFLUCC 19-0469	MN707567	MN707569
R. corticium	E32_II	KC311485	KC311485
R. necatrix	CBS 267.30	KF719201	MH866585
Selenodriella fertilis	CBS 772.83	KP859055	KP858992
Sordaria fimicola	CBS 723.96	MH862606	MH874231
Triangularia verruculosa	CBS 433.64	MH858480	MH870112
Vesiculozygosporium echinosporum	CBS 247.72	MH860466	—
	CPC 35607	MT223869	MT223940
	JCM 11115	AB073533	AB073534
Wawelia regia	CBS 1100	MH854595	MH866123
Xylaria longipes	DSM 107183	MK408619	MK408619
Zygosporium chartarum	CBS 384.53	—	MH868785
Z. gibbum	FMR 13130	KY853482	KY853546
	NBRC 30213	IF03021301*	IF03021301*
Z. masonii	CBS 138.71	MH860038	MH871818
	CBS 479.73	MH860748	MH872461
	CBS 557.73	MH860771	MH872493
	NBRC 30214	IF03021401*	IF03021401*
Z. minus	HKAS 99625	MF621586	MF621590
Z. mycophilum	CBS 396.49	MH856563	MH868080
	CBS 533.76	—	MH877824
	CBS 828.68	—	MH878406
	CBS 894.69	MH859474	MH871255
	NBRC 32050	IF03205001*	IF03205001*
	NBRC 9359	IF00935901*	IF00935901*
Z. oscheoides	CBS 195.79	MH861194	MH872964
	MFLUCC 14-0402	MF621585	MF621589
Z. pseudogibbum	CBS 143503[T]	MH107928	MH107974
	CBS 144442	MK442633	MK442568
Z. pseudomasonii	CPC 37503[T]	MN562147	MN567654

[T] Strains with type status

*Sequences and their accession numbers downloaded from the Biological Resource Center (NBRC), NITE, Japan (http://www.nite.go.jp/en/nbrc/cultures/index.html)

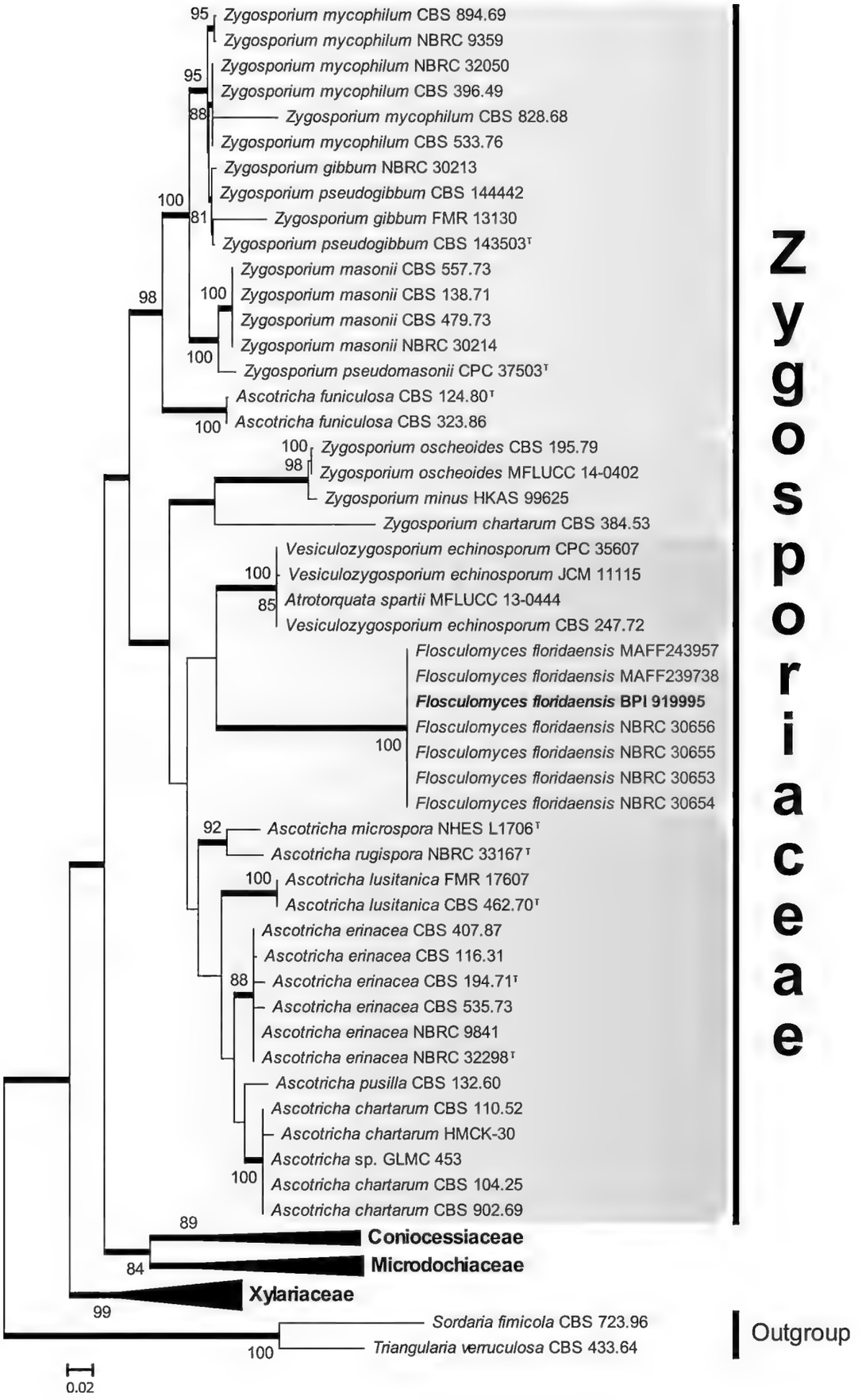
** Sequences downloaded from NARO Genebank database without accession numbers (https://www.gene.affrc.go.jp/databases_en.php)

(ITS) region together with the first 900 bp of the 5′ end of the nuclear ribosomal large subunit DNA (nrLSU) were PCR amplified, purified, and sequenced using the primers pairs ITS1/ITS4 and NL1/LR5 (O'Donnell 1992, Vilgalys & Hester 1990, White & al. 1990). The returned consensus sequences were checked and deposited in GenBank.

Taxon sampling and phylogenetic analyses

The newly generated ITS and LSU sequences were first subjected to megablast searches in GenBank to assess the phylogenetic placement of *F. floridaensis*. Closest hits were members of *Zygosporiaceae* and *Xylariaceae* (*Xylariales*), which were selected and used to assemble datasets for analyses. Unpublished ITS–LSU sequences belonging to six strains of *F. floridaensis* collected in Japan (Tanaka & al. 2017, Yokoyama & Ito 1989) were retrieved from the NBRC and NARO Genetic Resources Center websites and added to the datasets. Additional sequences belonging to recent phylogenies of *Zygosporiaceae* and related families (Li & al. 2017, Li & Zhao 2018, Crous & al. 2020, Konta & al. 2021) were also included. The strains *Sordaria fimicola* CBS 723.96 and *Triangularia verruculosa* CBS 433.64 (*Sordariales*) were selected as outgroup. All strains and sequences used in this study are listed in Table 1. Individual ITS and LSU datasets were aligned separately using MAFFT v 7.487 on the online server (Katoh & al. 2002), which automatically selected the FFT-NS-i strategy (Katoh & Standley 2013) for both loci. Phylogenetic reconstructions were first performed on individual datasets. Maximum likelihood (ML) was employed using RAxML v.8.2.10 (Stamatakis 2014) and Bayesian inference (BI) using MrBayes v. 3.2.7a (Ronquist & Huelsenbeck 2003) on the CIPRES Science Gateway server (Miller & al. 2010). Each analysis setting followed Delgado & al. (2022) with statistical support estimated for each node using bootstrap (BS) and posterior probabilities (BPP). Some topological differences existed between individual trees but recovered clades were identical and well supported. Therefore, datasets were concatenated in MEGA v. 6.06 (Tamura & al. 2013) for further ML and BI analyses following identical settings. Pairwise comparisons and best-fit substitution model selection were also performed in MEGA. The selected model for BI using the Akaike information criterion was GTR+G+I for all datasets. Trees were viewed in FigTree v1.4.2. (Rambaut 2009) or MEGA and edited on Inkscape (inkscape.org).

Fig. 1. RaxML phylogenetic tree inferred from combined ITS–LSU nrDNA sequences of *Zygosporiaceae* and related taxa in *Xylariales* showing the placement of *F. floridaensis* within the family. The new strain obtained in this study is in bold. Color boxes represent the five different lineages recovered: *Zygosporium* sensu lato (purple); *Zygosporium* sensu stricto (yellow); *Vesiculozygosporium* (green); *Flosculomyces* (pink) and *Ascotricha* (pale blue). Bootstrap support values ≥70% are shown at the nodes and Bayesian posterior probabilities ≥0.95 are indicated by thickened branches. ^{T} denotes strains with type status.


Zygosporium mycophilum CBS 894.69
Zygosporium mycophilum NBRC 9359
Zygosporium mycophilum NBRC 32050
Zygosporium mycophilum CBS 396.49
Zygosporium mycophilum CBS 828.68
Zygosporium mycophilum CBS 533.76
Zygosporium gibbum NBRC 30213
Zygosporium pseudogibbum CBS 144442
Zygosporium gibbum FMR 13130
Zygosporium pseudogibbum CBS 143503T
Zygosporium masonii CBS 557.73
Zygosporium masonii CBS 138.71
Zygosporium masonii CBS 479.73
Zygosporium masonii NBRC 30214
Zygosporium pseudomasonii CPC 37503T
Ascotricha funiculosa CBS 124.80T
Ascotricha funiculosa CBS 323.86
Zygosporium oscheoides CBS 195.79
Zygosporium oscheoides MFLUCC 14-0402
Zygosporium minus HKAS 99625
Zygosporium chartarum CBS 384.53
Vesiculozygosporium echinosporum CPC 35607
Vesiculozygosporium echinosporum JCM 11115
Atrotorquata spartii MFLUCC 13-0444
Vesiculozygosporium echinosporum CBS 247.72
Flosculomyces floridaensis MAFF243957
Flosculomyces floridaensis MAFF239738
Flosculomyces floridaensis BPI 919995
Flosculomyces floridaensis NBRC 30656
Flosculomyces floridaensis NBRC 30655
Flosculomyces floridaensis NBRC 30653
Flosculomyces floridaensis NBRC 30654
Ascotricha microspora NHES L1706T
Ascotricha rugispora NBRC 33167T
Ascotricha lusitanica FMR 17607
Ascotricha lusitanica CBS 462.70T
Ascotricha erinacea CBS 407.87
Ascotricha erinacea CBS 116.31
Ascotricha erinacea CBS 194.71T
Ascotricha erinacea CBS 535.73
Ascotricha erinacea NBRC 9841
Ascotricha erinacea NBRC 32298T
Ascotricha pusilla CBS 132.60
Ascotricha chartarum CBS 110.52
Ascotricha chartarum HMCK-30
Ascotricha sp. GLMC 453
Ascotricha chartarum CBS 104.25
Ascotricha chartarum CBS 902.69
Coniocessiaceae
Microdochiaceae
Xylariaceae
Sordaria fimicola CBS 723.96
Triangularia verruculosa CBS 433.64
Zygosporiaceae
Outgroup
0.02

Phylogenetic results

Pairwise comparisons between the ITS and LSU sequences of the Texas and Japanese strains of *F. floridaensis* showed they were identical along the lengths of their 483 ITS and 560 LSU aligned positions. The combined ITS–LSU alignment consisted of 77 sequences (including the outgroup sequences) and 1522 positions—627 from the ITS and 895 from the LSU datasets. The best scoring RAxML tree (ln = −12408.076162) is shown in Fig. 1. The tree was identical in topology to the 50% majority rule consensus tree of the 12001 trees sampled during the Bayesian analysis. The seven strains of *F. floridaensis* formed a strongly supported monophyletic group (the *Flosculomyces* lineage; 100% BS, 1 BPP) within *Zygosporiaceae* J.F. Li & al. They grouped sister to another strongly supported clade (100% BS, 1 BPP), including three strains of *Vesiculozygosporium echinosporum* (Bunting & E.W. Mason) Crous and another strain named *Atrotorquata spartii* Thambug. & al. (the *Vesiculozygosporium* lineage), but without significant support. *Ascotricha* strains grouped together in a weakly supported clade (the *Ascotricha* lineage) with the exception of the two available strains of *A. funiculosa* (Guarro & Calvo) D.W. Li & G.H. Zhao including an ex-type CBS 124.80. Both strains were recovered as sister to the fully supported *Zygosporium* sensu lato lineage (100% BS, 1 BPP), including species such as *Z. mycophilum* (Vuill.) Sacc., *Z. gibbum* (Sacc. & al.) S. Hughes, and *Z. masonii* S. Hughes, with strong support (98% BS, 0.99 BPP). The *Zygosporium* sensu stricto clade including *Z. oscheoides* Mont. (the generic type), received significant support only in the Bayesian analysis (0.99 BPP). It was resolved sister to a subclade formed by *Vesiculozygosporium*, *Flosculomyces,* and *Ascotricha* lineages with significant BPP support (0.99). *Zygosporiaceae* was recovered as a monophyletic clade but having only significant Bayesian support (0.98 BPP). Some topological incongruences were observed between individual trees. They include the placement of the *Flosculomyces* clade outside *Zygosporiaceae* in the ITS tree or the position of *A. rugispora* NBRC 33167 outside the *Ascotricha* clade in the LSU tree (not shown). However, the different lineages recovered were identical and strongly or similarly supported in all analyses.

Taxonomy

Flosculomyces floridaensis B. Sutton, Mycologia 70(4): 789, 1978. Fig. 2

Colonies on MEA moderately fast growing reaching 22–24 mm diam. after 7 days at 25°C, velvety, white, center cream or dull white, flat, sometimes slightly sulcate, margin entire, reverse dull white, readily sporulating at

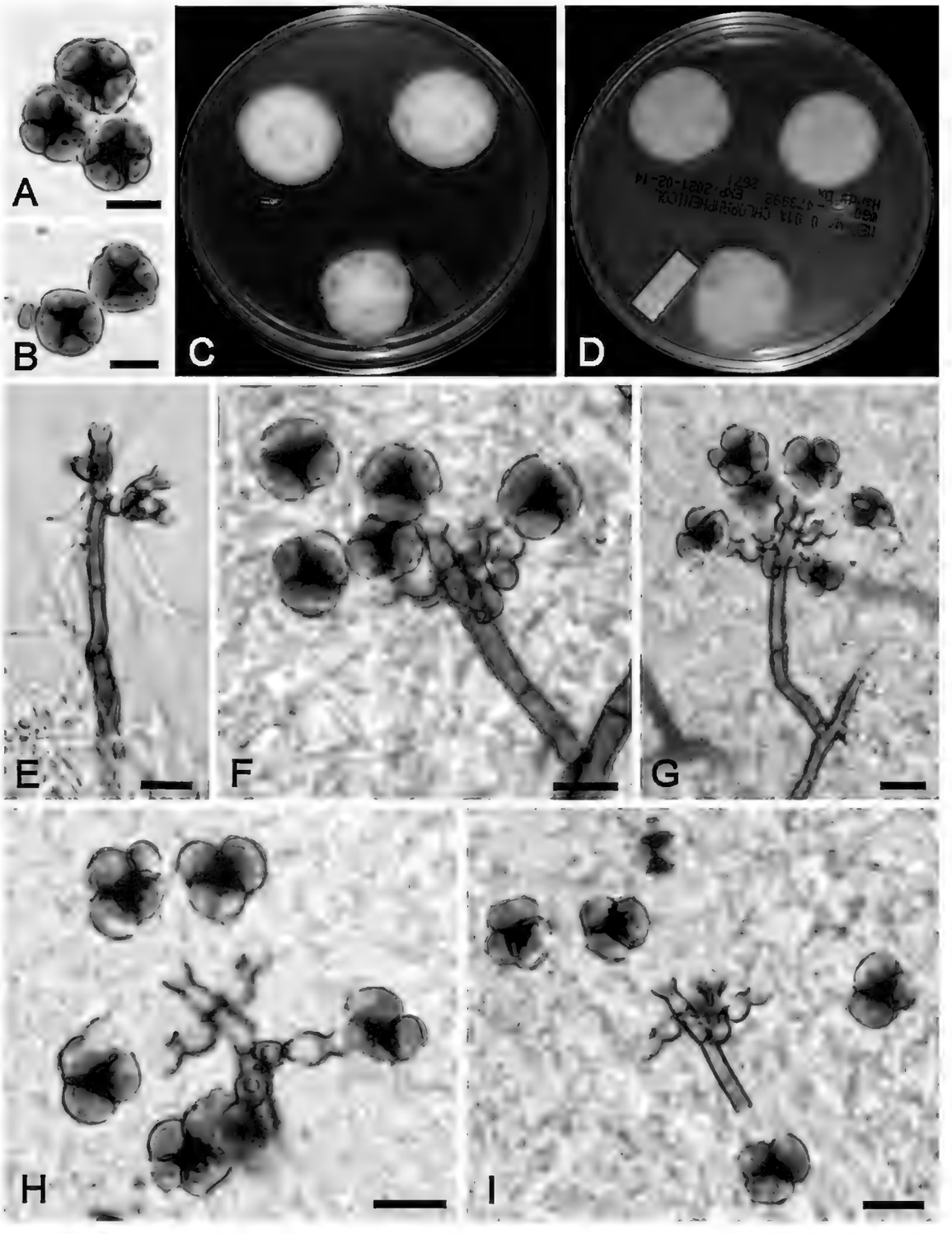


Fig. 2. *Flosculomyces floridaensis* (BPI 928572): A, B. Airborne conidia (BPI 919995); C, D. Colonies on MEA after 7 days at 25°C (C. Surface view; D. Reverse); E. Conidiophore with apical branches and conidiogenous cells; F, G. Conidiophores, branches, conidiogenous cells, and conidia; H, I. Apical branches, conidiogenous cells; and mostly 3-celled conidia. Scale bars = 10 μm.

first but declining to almost sterile after repeated subculturing. MYCELIUM immersed and superficial, composed of branched, septate, smooth, hyaline immersed hyphae, 1.5–2 µm wide, subhyaline to pale brown in mass, and smooth or irregularly verruculose, pale brown to brown, superficial hyphae, (2–)3–5 µm wide, some cells or segments thick-walled and swollen, 4.5–7 µm wide. CONIDIOPHORES arising terminally or laterally on the superficial hyphae, macronematous, mononematous, erect, straight or flexuous, branched toward the apex or rarely simple, septate, smooth, brown, up to 121 µm long, 3–4 µm wide; BRANCHES intercalary and lateral on the conidiophores, formed below the septa, single or in whorls of 2–3, pale brown to brown, subcylindrical, sometimes slightly swollen at the base, 6–9(–12) × 4–6 µm wide. CONIDIOGENOUS CELLS monoblastic, determinate, integrated and terminal or intercalary and lateral on the conidiophores or discrete on lateral branches, ampulliform, constricted in the middle, 6–10 µm long, 3–5 µm at the base, rounded at the apex, brown, paler toward the apex, sometimes cupulate after conidial detachment, 3.5–6 µm wide at the apex. CONIDIA acrogenous, consisting of three or four cells, more or less round, lobed, cruciately septate, constricted at the septa, smooth, brown, darkly pigmented in the center, paler toward the periphery, 10–16 µm diam., horizontally flattened and black at base in lateral view, 6–7 µm thick.

SPECIMENS EXAMINED—**UNITED STATES. TEXAS: Montgomery Co.**, The Woodlands 77384, 30.2051°N 95.4582°W, from indoor air collected using a pre-cultured MEA plate, isol. G. Delgado, 9.XII.2020 (BPI 919995); **Harris Co.**, Houston 77096, from outdoor air collected on a glass slide inside an Air-O-Cell sampling cassette, 28.V.2021, det. G. Delgado (BPI 928571); Kingwood 77345, from outdoor air collected on a glass slide inside an Air-O-Cell sampling cassette, 3.VI.2021, det. G. Delgado (BPI 928572).

COMMENTS—Our isolate and the other two specimens consisting of only airborne conidia agree well with the species protologue in morphology and conidial dimensions, 13–16.5 µm diam. and 7–8 µm thick. However, a mixture of conidia (predominantly 3-celled) was present in the cultured isolate (FIG. 2H, I), whereas 4-celled conidia dominated the airborne samples (FIG. 2A, B). The presence of both three or four-celled conidia in *F. floridaensis* specimens has been previously reported in culture or natural substrate. Matsushima (1989) mentioned the production of conidia having both three or four lobes on corn meal and V8 agar media. Yokoyama & Ito (1989) and Ono & Kobayashi (2005) described conidia usually consisting of four or (rarely) three cells, whereas Marques & al. (2007) mentioned both smaller, 3-celled conidia and slightly larger, 4-celled conidia for materials

collected from the same substrate and locality. Apparently, age and growing conditions, whether on the host, indoor, subject to air dispersion, or in culture, influence the production of conidia with a greater or fewer number of cells. This may suggest that morphological boundaries between the two accepted species, mainly separated by the number of conidial cells, are fuzzy and the validity of *F. trilobatus* needs to be tested in the light of molecular data. In culture, our isolate matched well those of Yokoyama & Ito (1989) in being white at first, grayish salmon color with age on MEA. Unfortunately, successive sub-culturing affected its sporulation and the Texas isolate decreased capacity to the point of becoming nearly sterile after two months.

Discussion

In the present study, the taxonomic placement of *Flosculomyces floridaensis* is investigated for the first time based on nuclear ribosomal DNA sequence data obtained from strains collected in Japan and the USA. The position of the fungus in *Zygosporiaceae* (*Xylariales*, *Sordariomycetes*) revealed a novel and distinct lineage within the family. *Flosculomyces* is therefore recognized as a phylogenetically well-circumscribed genus in agreement with its peculiar and unique morphology. Based on ribosomal DNA sequence data and strains collected in Thailand, China, and Spain, Li & al. (2017) validly reintroduced the name *Zygosporiaceae* to accommodate three species of *Zygosporium* Mont.: *Z. oscheoides* (the generic type), *Z. minus* S. Hughes, and *Z. gibbum*. The genus forms a well-supported monophyletic lineage within the *Xylariales* sister to *Coniocessiaceae* Dania García & al. and molecular results were also consistent with the unique morphology of its members. *Zygosporium* is characterized by hyphomycetous anamorphs having darkly pigmented, incurved vesicular cells that may be stalked or sessile and borne from the side of a setiform conidiophore or arise directly from the mycelium giving rise to 2–4 ampulliform conidiogenous cells producing aseptate, typically ellipsoid or globose, smooth or variously ornamented conidia (Whitton & al. 2003, 2012). Later, sequence data for additional species such as *Z. chartarum* Camposano, *Z. masonii,* and *Z. mycophilum* became available in GenBank for strains deposited in CBS (Vu & al. 2019). Two novel species, *Z. pseudomasonii* Crous and *Z. pseudogibbum* Crous, were also described using DNA sequence data (Crous 2019, Crous & al. 2018, 2019) together with a new genus *Vesiculozygosporium* Crous based on *Z. echinosporum* Bunting & E.W. Mason (Crous & al. 2020). On the other hand, the holomorphic genus *Ascotricha* Berk. has been traditionally accepted within *Xylariaceae* (Cheng & al. 2015,

Wijayawardene & al. 2020). However, with the availability of DNA sequence data for *Zygosporium* species, Hyde & al. (2020) recently recognized the close phylogenetic affinities between these two genera. Subsequent studies have included *Ascotricha* within *Zygosporiaceae* distant from *Xylariaceae* (Crous & al. 2019, 2020) and our phylogeny was also consistent with these results.

With the placement of *Flosculomyces* in *Zygosporiaceae*, the family apparently includes disparate morphologies based on their anamorphs that can be easily recognized as five distinct and well delimited lineages (Fig. 1). The typical vesiculate, setiform conidiophores and aseptate, ellipsoidal or globose conidia of the *Zygosporium* and *Vesiculozygosporium* lineages contrast with the branched conidiophores and cruciately septate conidia of *Flosculomyces*. They are also dissimilar to the dichotomously or trichotomously branched conidiophores of the dicyma-like anamorphs of *Ascotricha*, having sterile, clavate extensions and sympodial, denticulate conidiogenous cells (Ellis 1971). Moreover, *Ascotricha* is so far the only member of *Zygosporiaceae* producing teleomorphic states. They are characterized by ostiolate or non-ostiolate, long setose ascomata with a translucent peridial wall, 8-spored asci and brown ellipsoidal ascospores with an equatorial germ slit (Stchigel & Guarro 1998, Cheng & al. 2015). Curiously, the sterile elements of setae and conidiophores in *Ascotricha* and *Zygosporium* suggest a morphological connection between them. The capitate, vesiculate or spathulate cells developing at the tips or at the geniculations and dichotomous branches of setae in the ascomata and conidiophores of *Ascotricha* species show some resemblance with the capitate, slightly swollen to spherical apical vesicles of setae and setiform conidiophores of *V. echinosporum*, *Z. minus* and *Z. oscheoides* (Hawksworth 1971, Hughes 1951). They also resemble the long, apically swollen or the short cylindrical sterile cells at the apex of the vesicular conidiophores of *Z. masonii*, *Z. gibbum*, and *Z. mycophilum*. From a morphological standpoint, these shared features may help to support further the recent placement of *Ascotricha* in *Zygosporiaceae*.

Interestingly, *Zygosporium* was resolved as paraphyletic within the family (Fig. 1). Morphologically, the genus was split according to whether or not vesicles are always produced at the side of the setiform conidiophores, and if they are not, whether vesicles are always or sometimes borne directly on the superficial mycelium accompanied by setae or without them. The *Zygosporium* sensu stricto lineage includes the generic type *Z. oscheoides*, together with *Z. chartarum* and *Z. minus*. The three species are characterized by the production of vesicles usually at the base of the setiform conidiophores.

On the other hand, the *Zygosporium* sensu lato lineage, at the moment the most specious one, includes *Z. gibbum*, *Z. pseudogibbum*, *Z. mycophilum*, *Z. masonii*, and *Z. pseudomasonii*. This group has in common the lack of setae and the presence of vesicles borne on stalk cells that arise directly on the superficial mycelium. The third lineage includes *Vesiculozygosporium* and consists of a single species, *V. echinosporum*, characterized by stalk vesicles either arising directly from the superficial mycelium or borne along the length of setiform conidiophores that sometimes are sterile, do not produce any vesicles, and therefore are considered true setae (Whitton & al. 2003, Li & al. 2017). A LSU sequence under the name *Atrotorquata spartii* MFLUCC 13-0444 clustered together with *V. echinosporum*. Crous & al. (2020) explained that there are inconsistences between this sequence and its ITS counterpart, and therefore it was only included in our phylogeny because of its 100% identity with the LSU sequence of strain CPC 35607. Further support for this lineage was obtained by adding strains CBS 247.72 and JCM 11115, the latter originally isolated from a nest of a termite *Odontotermes* sp. in Thailand as an unknown xylariaceous taxon (Taprab & al. 2002) but later identified as *V. echinosporum* (https://jcm.brc.riken.jp/en/catalogue_e). Additionally, the three lineages revealed in *Zygosporium* agree well with the morphological categories used in previous dichotomous keys to identify species of the genus (Whitton & al. 2003, 2012). According to Index Fungorum (http://www.indexfungorum.org), *Zygosporium* currently includes 28 species in contrast to only nine taxa currently available in GenBank. More strains representing other species and additional DNA sequence data will help to further test the hypothetical lineages revealed in this work for possible generic redisposition in the future.

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Albophoma belongs in *Ophiocordycipitaceae*, with a new record from China

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Abstract—A fungus isolated from forest soil in Guizhou Province, China, was identified by morphology and phylogenetic analyses as *Albophoma yamanashiensis*, a new record from China. The combined ITS+LSU phylogenetic tree places *Albophoma* (previously a conidial coelomycetous genus of unknown affinity) in *Ophiocordycipitaceae* and sister to *Tolypocladium*.

Key words—family classification, *Hypocreales, Sordariomycetes,* taxonomy

Introduction

Albophoma was established as a monotypic genus by Kobayashi & al. (1994), typified by *A. yamanashiensis* isolated from forest soil in Yamanashi Prefecture, Japan. *Albophoma* has been classified as a conidial coelomycetous genus of unknown affinity, characterized by pure white fleshy pycnidia and small globular conidia with many frills on their wall surfaces and a thick basal scar. No additional *Albophoma* species have been proposed (http://www.mycobank.org).

During a survey of soil coelomcycete diversity in southwest China's Guizhou Province, we isolated two fungal strains that showed the

§ W.Y. Jia and J.J. Xu contributed equally to this work.

Table 1. Sequences used in phylogenetic analyses.

Species	Strain	GenBank accession no.	
		ITS	LSU
Cordyceps militaris	OSC 93623	JN049825	AY184966
C. kyusyuensis	EFCC 5886	—	EF468813
Polycephalomyces formosus	ARSEF1424	KF049661	KF049634
P. ramosus	MFLU 18-0162 T	MK863250	MK863050
Purpureocillium lilacinum	CBS 284.36T	AY624189	—
	CBS 431.87	AY624188	EF468844
P. takamizusanense	NHJ 3497	—	EU369033
Perennicordyceps prolifica	NBRC 101750	JN943340	JN941433
	NBRC 103838	JN943339	JN941434
P. cuboidea	NBRC 100941	AB378666	AB378646
	NBRC 101742	AB378667	AB378648
P. paracuboidea	NBRC 101742	—	KF049630
P. ryogamiensis	NBRC 103837	—	JN941439
Tolypocladium capitatum	NBRC 106327	JN943317	JN941404
T. inflatum	CBS 567.84 T	MH861779	MH873477
T. japonicum	OSC 110991	JN049824	DQ518761
T. ophioglossoides	NBRC 106331	JN943320	JN941408
Ophiocordyceps melolonthae	OSC 110993	—	DQ518762
	Ophgrc679	—	KC610768
O. variabilis	ARSEF 5365	—	DQ518769
	OSC 111003	—	EF468839
Hirsutella fusiformis	ARSEF 5474	—	KM652110
H. liboensis	ARSEF 9603 T	KM652163	KM652115
H. lecaniicola	ARSEF 8888	KM652162	KM652114
H. illustris	ARSEF 5539	KM652160	KM652112
Paraisaria orthopterorum	TBRC 9710 T	MH754743	MK332582
P. phuwiangensis	BBH 43491 T	MH188542	MK192058
P. rosea	HKAS 102546	MN947222	MN943842
P. heteropoda	EFCC 10125	JN049852	EF468812
P. coenomyiae	NBRC 106964	AB968397	AB968413
Albophoma yamanashiensis	JCM 11844 T	LC228661	LC228718
	HGUP 20-8	**OK559516**	**OK562790**
	HGUP 20-50	**OK559517**	**OK562791**

Type strains are marked by T. New sequences are set in **bold** font.

morphological characters of *A. yamanashiensis* on potato dextrose agar (PDA). Based on morphological and ITS and LSU sequence analyses, we found the two strains were conspecific and identified them as *A. yamanashiensis*, a new record from China. The phylogeny supports *Albophoma* in *Ophiocordycipitaceae* G.H. Sung & al. (Sung & al. 2007), as a sister genus to *Tolypocladium* W. Gams.

Materials & methods

Samples, fungal isolates, morphological observations

Soil samples were collected in 2019 from Fodingshan National Nature Reserve in Shiqian County, Guizhou Province, China, and a plate dilution method was used to isolate soil fungi (Turmel & al. 2010). The conidiophores and conidia were morphologically examined and photographed at 400× and 1000× with a Nikon 90i microscope. The specimens were conserved in the Herbarium of the Department of Plant Pathology, Agricultural College, Guizhou University, China (HGUP).

DNA extraction, amplification, sequencing

Genomic DNA was extracted from the fresh mycelia grown on PDA, using the Biomiga Fungal gDNA Kit GD2416 following the manufacturer's instructions. The primers ITS4/ITS5 (White & al. 1990) were used for the ITS region amplification, and LR0R/LR5 were used to amplify a segment of the large subunit rDNA (Vilgalys & Hester 1990). The purified PCR products were sequenced by Sangon Biotech Co., Ltd. Sequences were downloaded from GenBank for phylogenetic analyses, and the newly generated sequences were deposited in GenBank (Table 1).

Sequence analyses

The newly generated sequences were compared with related sequences by BLAST searches. Sequences were aligned using MAFFT v.6 (Katoh & Toh 2010) and edited manually using MEGA 6.0. The combined ITS and LSU rDNA sequences were analyzed phylogenetically using Maximum Parsimony (MP), Maximum Likelihood (ML), and Bayesian Inference (BI). MP analysis was performed using PAUP* 4.0b10 (Swofford 2003). ML analysis was conducted using RAxML-HPC BlackBox v.8.2.12 (Stamatakis 2014) via the CIPRES Science Gateway platform (Miller & al. 2010) with 1000 bootstrap replicates. The model for BI analysis was determined using jModelTest 2.0 (Posada 2008), and TIM2+I+G was estimated as the best-fit model under the output strategy of Akaike Information Criterion (AIC). BI analysis was performed via MrBayes v3.2.7 (Ronquist & al. 2012). The phylogenetic tree was viewed in FigTree v1.4.4 and edited in Adobe Illustrator CS5 (AI).

Taxonomy

Albophoma yamanashiensis Tak. Kobay., Masuma, Ōmura & Kyoto Watan., Mycoscience 35 (4): 399 (1994) Fig. 1

Colonies on PDA flat, white, attaining 20 mm diam. after 3 weeks at 28°C, with numerous pycnidia on the surface. Mycelium superficial, hyphae hyaline, septate, smooth, branched, 2–3.7 µm wide. Conidiophores arising from the inner hyphae of pycnidium, producing conidia holoblastically. Pycnidia white, globular or somewhat oblate, 120–185 µm in diam. Conidia one-celled, hyaline, globular, 0.7–2.0 µm in diam.

Specimens examined: **CHINA, Guizhou Province, Shiqian County**, Fodingshan National Nature Reserve, 1164 m asl, from a forest soil sample, 17 October 2019, W.Y. Jia (HGUP 20–8; GenBank OK559516, OK562790); (HGUP 20–50; GenBank OK559517, OK562791).

Phylogeny

The ML phylogenetic tree is shown (Fig. 2), with *Cordyceps militaris* and *C. kyusyuensis* as outgroup. The 31 ingroup sequences grouped within *Ophiocordycipitaceae*, which formed two large branches with full bootstrap support (ML/MP/BI = 100%/100%/1). The sequences generated from our two strains, HGUP 20–8 and HGUP 20–50 clustered together with an ex-type strain of *A. yamanashiensis* in a fully supported clade (ML/MP/BI = 100%/100%/1), and was sister to the *Tolypocladium* group (ML/MP/BI = -/60%/1). Therefore, phylogenetic analyses based on two gene loci support the identification of the two strains as *A. yamanashiensis* and identify *Albophoma* as belonging in *Ophiocordycipitaceae*.

Discussion

Our two Chinese strains identified as *A. yamanashiensis* are morphologically very similar to the fungus described by Kobayashi & al. (1994), and their ITS and LSU sequences confirmed this identification. Additionally, although *Albophoma* is phylogenetically close to *Tolypocladium* in the phylogram of *Ophiocordycipitaceae* (Fig. 2), there are obvious morphological differences separating the two genera. *Tolypocladium* is easily distinguished by its usually swollen phialides that give rise to conidia enteroblastically, and it produces no fleshy, white pycnidia (Gams 1971, Wang & al. 2022). Both morphological and phylogenetic analyses place our strains HGUP 20–8 and HGUP 20–50 as *A. yamanashiensis* within *Ophiocordycipitaceae*.

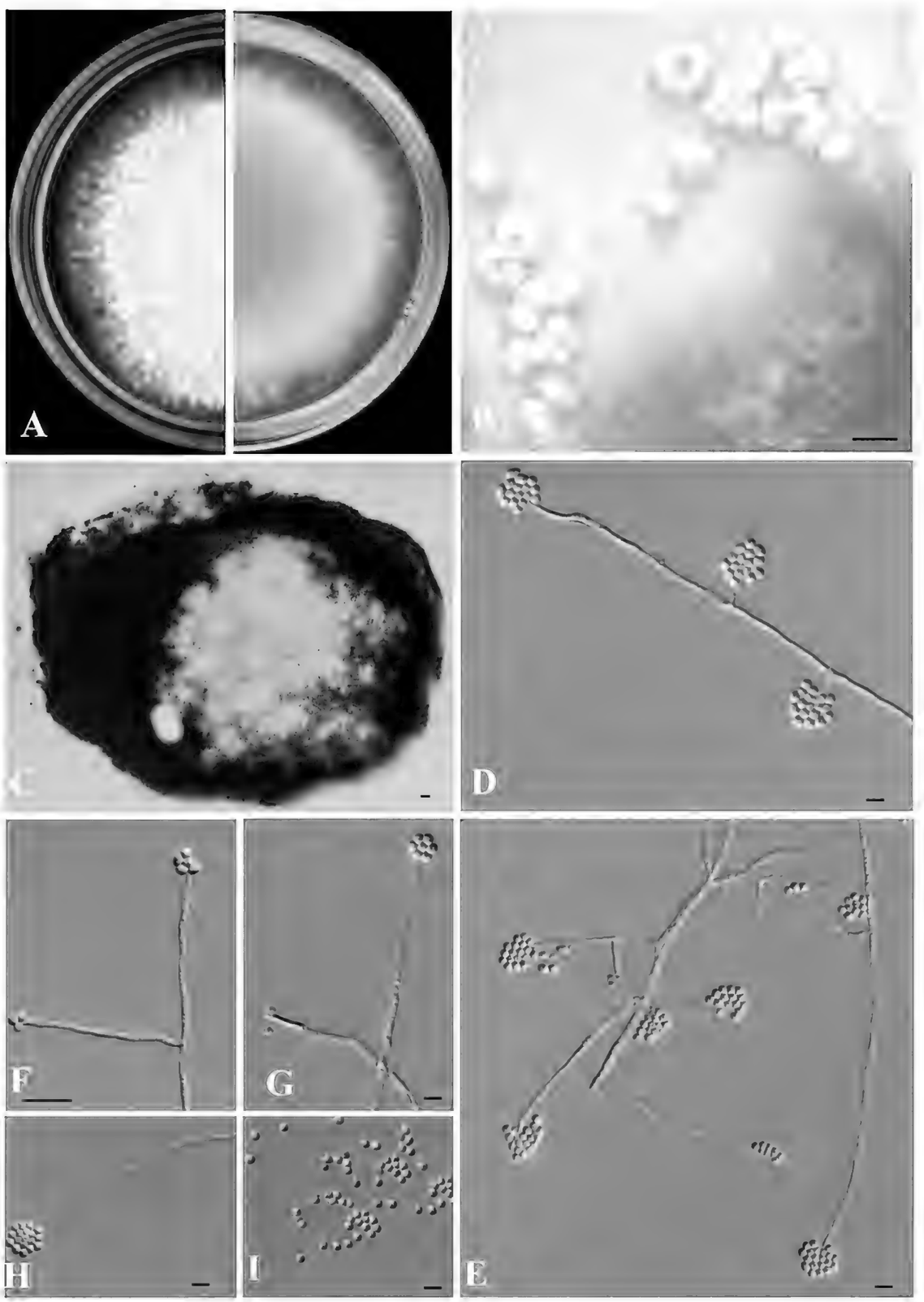

Fig. 1. *Albophoma yamanashiensis* (HGUP 20–50). A: Colony on PDA for three weeks producing many pycnidia; B: White, globular pycnidia; C: Cross section of pycnidium having numerous minute conidia; D–I: Acremonium-type conidia. Scale bars: B = 1 mm; C = 100 µm; D–I = 50 µm.

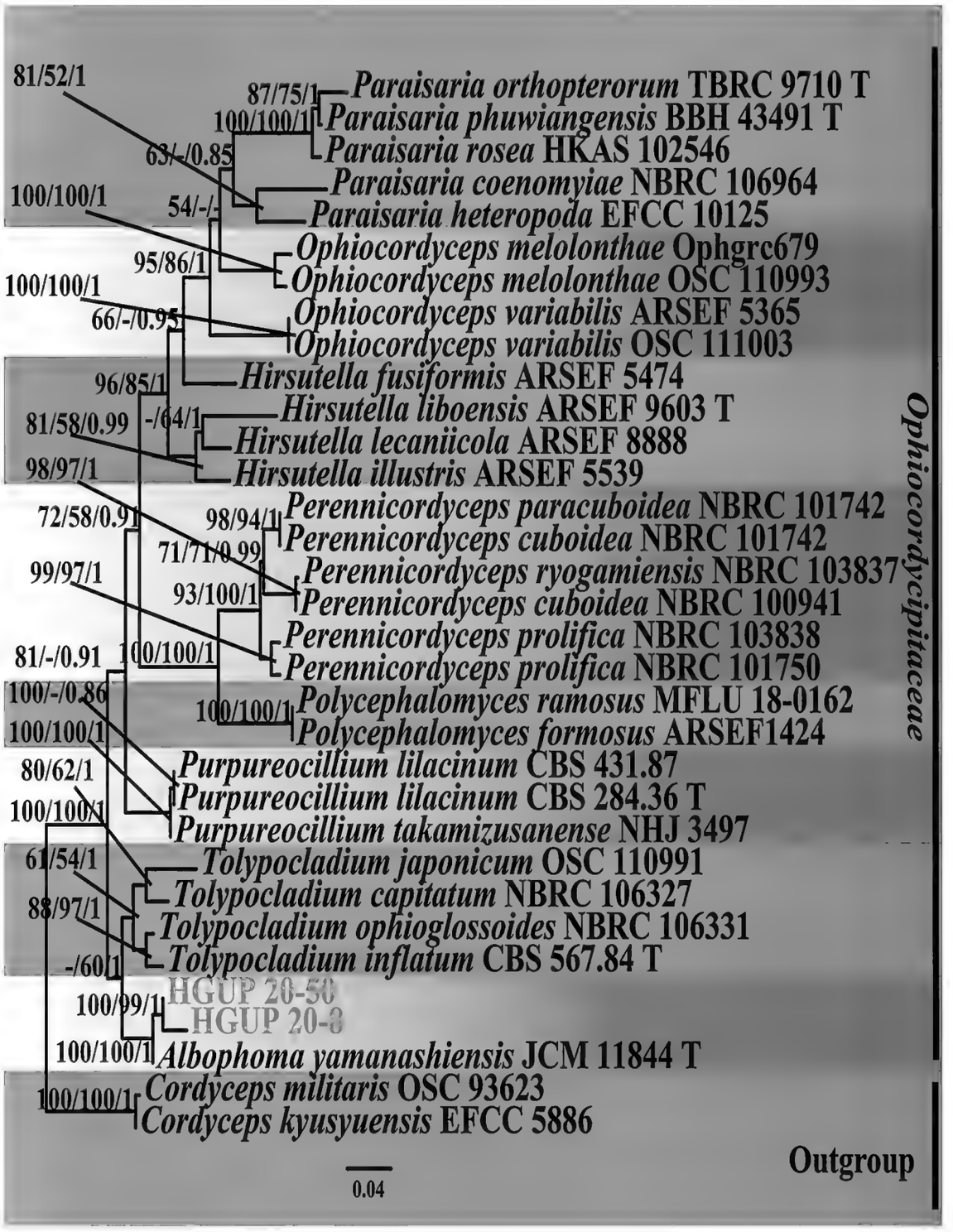

Fig. 2. The system diagram generated by Maximum Likelihood analysis of the combined LSU and ITS sequence data. Branch support displayed at the nodes as: Maximum Likelihood and Maximum Parsimony bootstrap support values >50% / Bayesian posterior probabilities ≥0.85. *Cordyceps militaris* and *C. kyusyuensis* are used as outgroup. Our strains are set in red font, and ex-type strains are marked by T.

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Gender of fungal generic names ending in *–trema*

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Abstract—Fungal generic names ending in *–trema* are reviewed. Most are derived from the latinised Greek neuter noun meaning "perforation; aperture; opening; orifice." However, some are Latin feminine, with *–trema* referring to a relationship or similarity to *Tremella*.

Key words—etymology, epithet gender, lichens, nomenclature, *Tremellales*

Introduction

Numerous fungal generic names ending in *–trema* are derived from the Greek neuter noun τρημα, meaning "perforation; aperture; opening; orifice." Most of these are lichen genera, with names referring to characteristics of their ascomatal ostioles.

It has been widely assumed that all generic names ending in *–trema* have neuter gender, regardless of their etymology. However, there are several tremellalean genera where the ending *–trema* has been treated as a Latin feminine, apparently intended as an abbreviation alluding to their affinity with *Tremella*.

A similar mix of implied genders occurs among botanical and algal names. Of 14 plant genera ending in *–trema* (IPNI 2022), nine have neuter species epithets, four have feminine epithets, and one has no listed species. Of seven algal genera ending in *–trema* (AlgaeBase 2022), two have neuter species epithets, three have feminine epithets, and two have no listed species; moreover the AlgaeBase website explicitly lists the "accepted gender" of three of these genera—one as neuter and two as feminine. The protologues of these botanical

and algal genera need to be checked to confirm whether or not they are derived from Greek τρημα.

Here, a listing of all fungal *–trema* genera is presented, with the evidence for their gender compiled and annotated, including comments on the orthography of higher taxon names typified by such genera.

Materials & methods

Two of the three major fungal nomenclature websites, Index Fungorum (2022) and MycoBank (2022), were interrogated to compile a list of all fungal *–trema* genera. Evidence of their gender was ascertained by investigating: (a) the gender of adjectival epithets published by the original and subsequent authors of species; (b) etymologies (either published or implied by the generic descriptions); and (c) the orthography of higher taxa typified by them.

Results & discussion

Fifty fungal genera ending with *–trema* were located and classified into four groups: 35 lichenised neuter genera; eight non-lichenised neuter genera; six Latin feminine genera; and one microsporidial (feminine?; neuter?) genus.

Lichenised genera with names based on Greek τρημα (neuter)

Mycasterotrema is a nomen nudum; and *Prototrema* is rather obscure and apparently has no named species. All but two of the remaining 33 genera in this group have neuter adjectival epithets, either in the holotype or in other species (if the holotype epithet is gender uninformative). *Sanguinotrema* (*Graphidaceae*) is a monotypic genus with an uninformative epithet. *Xerotrema* (*Odontotremataceae*) was published as a monotypic genus with a feminine holotype epithet and a subsequently included second species has an uninformative epithet; I have corrected the holotype epithet to the neuter form.

Four tribes, four families, and one order are typified by genera in this group; these names are formed from Greek neuter linguistic stems, resulting in the terminations ***–trematea****e,* ***–trematac****eae,* or ***–tremat****ales.*

Acanthotrema Frisch (Frisch 2006: 77)

Type: *Acanthotrema brasilianum* (Hale) Frisch

Amazonotrema Kalb & Lücking (Kalb 2009: 18)

Type: *Amazonotrema nigrum* Kalb & Lücking

Ampliotrema Kalb (Frisch 2006: 81)

Type: *Ampliotrema amplius* (Nyl.) Kalb [a neuter comparative epithet]

Asterotrema Müll. Arg. (Müller [Argovensis] 1884: 19)
Type: *Asterotrema parasiticum* Müll. Arg.

Austrotrema I. Medeiros, Lücking & Lumbsch (Medeiros & al. 2017: 14)
Type: *Austrotrema bicinctulum* (Nyl.) I. Medeiros & al.

Borinquenotrema Merc.-Díaz, Lücking & Parnmen (Mercado-Díaz & al. 2014: 191)
Type: *Borinquenotrema soredicarpum* Merc.-Díaz & al.

Byssotrema M. Cáceres, Aptroot & Lücking (Cáceres & al. 2014: 91)
Type: *Byssotrema mirabile* M. Cáceres & al.

Clandestinotrema Rivas Plata, Lücking & Lumbsch (Rivas Plata & al. 2012a: 116)
Type: *Clandestinotrema clandestinum* (Ach.) Rivas Plata & al.

Coccotrema Müll. Arg. (Müller [Argovensis] 1889: 171)
Type: *Coccotrema antarcticum* Müll. Arg.
Coccotremataceae Henssen ex J.C. David & D. Hawksw. (David & Hawksworth 1991: 14)

Compositrema Rivas Plata, Lücking & Lumbsch (Rivas Plata & al. 2012b: 1172)
Type: *Compositrema cerebriforme* J.E. Hern. & Lücking

Conotrema Tuck. (Tuckerman 1848: 278)
Type: *Conotrema urceolatum* (Ach.) Tuck.

Cruentotrema Rivas Plata, Papong, Lumbsch & Lücking (Rivas Plata & al. 2012a: 116)
Type: *Cruentotrema cruentatum* (Mont.) Rivas Plata & al.

Cryptoschizotrema Aptroot, Lücking & M. Cáceres (Hyde & al. 2019: 129)
Type: *Cryptoschizotrema cryptotrema* (Nyl.) Aptroot & al.
Additional sp.: *Cryptoschizotrema minus* E.L. Lima & Lücking [a neuter comparative epithet] (Lima & al. 2019: 417)

Enigmotrema Lücking (Sipman & al. 2012: 66)
Type: *Enigmotrema rubrum* Lücking

Glaucotrema Rivas Plata & Lumbsch (Rivas Plata & al. 2012b: 1174)
Type: *Glaucotrema glaucophaenum* (Kremp.) Rivas Plata & Lumbsch

Gymnotrema Nyl. (Nylander 1858: 119)
Type: *Gymnotrema atratum* (Fée) Nyl.

Gyrotrema Frisch (Frisch & Kalb 2006: 379)
Type: *Gyrotrema sinuosum* (Sipman) Frisch

Leptotrema Mont. & Bosch (Montagne 1856: 363)
Syntypes: *Leptotrema zollingeri* Mont. & Bosch; *L. prevostianum* (Mont.) Mont.
Leptotremateae Lumbsch, Kraichak & Lücking (Lumbsch & al. 2014: 47)

Melanotrema Frisch (Frisch & Kalb 2006: 382)
Type: *Melanotrema platystomum* (Mont.) Frisch

Mycasterotrema Räsänen (Räsänen 1943: 22, as "[435. Mycasterotrema Räs.]", nom. nud.)
= *Asterotrema* Müll. Arg. (Lamb 1963: 421)

Myriotrema Fée (Fée 1825: xlix, 103)
Type: *Myriotrema olivaceum* Fée

Odontotrema Nyl. (Nylander 1858: 143)
Type: *Odontotrema phacidioides* Nyl.
Additional sp.: *Odontotrema minus* Nyl. [a neuter comparative epithet] (Nylander & Saelan 1859: 91)
Odontotremataceae D. Hawksw. & Sherwood (Hawksworth & Sherwood 1982: 263)
Odontotrematales Lücking (Lücking 2019: 233)

Parmotrema A. Massal. (Massalongo 1860: 248)
Type: *Parmotrema perforatum* (Jacq.) A. Massal.

Phaeotrema Müll. Arg. (Müller [Argovensis] 1887: 10)
Type: *Phaeotrema subfarinosum* (Fée) Müll. Arg.

Plagiotrema Müll. Arg. (Müller [Argovensis] 1885: 387)
Type: *Plagiotrema cubanum* Müll. Arg.

Pleurotrema Müll. Arg. (Müller [Argovensis] 1885: 388)
Type: *Pleurotrema polysemum* (Nyl.) Müll. Arg.
Pleurotremataceae Walt. Watson (Watson 1929: 113)

Prototrema M. Choisy (Choisy 1928: tab. 18)
= *Thelotrema* Ach. (Lamb 1963: 595)

Pycnotrema Rivas Plata & Lücking (Rivas Plata & al. 2012a: 120)
Type: *Pycnotrema pycnoporellum* (Nyl.) Rivas Plata & Lücking

Sanguinotrema Lücking (Lücking & al. 2015: 441)
Type: *Sanguinotrema wightii* (Taylor) Lücking
Sanguinotremateae Lücking, Kraichak & Lumbsch (Lücking & al. 2015: 442)

Schizotrema Mangold & Lumbsch (Mangold & al. 2009: 348, 657)
Type: *Schizotrema zebrinum* Mangold

Thelotrema Ach. (Acharius 1803: 130)
Type: *Thelotrema lepadinum* (Ach.) Ach.
Thelotremateae Rivas Plata, Lücking & Lumbsch (Rivas Plata & al. 2012a: 114)
Thelotremataceae Stizenb. [as "*Thelotremeae*"] (Stizenberger 1862: 167)

Trichotrema Clem. (Clements 1909: 41, 173)
Type: *Trichotrema trichosporum* (Müll. Arg.) Clem.

Trinathotrema Lücking, Rivas Plata & Mangold (Lücking & al. 2011: 195)
Type: *Trinathotrema stictideum* (Nyl.) Lücking & al.

Wirthiotrema Rivas Plata, Kalb, Frisch & Lumbsch (Rivas Plata & al. 2010: 198)
Type: *Wirthiotrema glaucopallens* (Nyl.) Rivas Plata & Kalb
Additional sp.: *Wirthiotrema duplomarginatum* Lücking & al. (Sipman & al. 2012: 202)
Wirthiotremateae Lumbsch, Kraichak & Lücking (Lumbsch & al. 2014: 47)

Xerotrema Sherwood & Coppins (Sherwood & Coppins 1980: 368)
Type: *Xerotrema megalosporum* Sherwood & Coppins [as "*megalospora*"]

Non-lichenised genera with names based on Greek τρημα (neuter).

The eight genera in this group are from diverse asco- and basidiomycete families or orders (as annotated below). *Hydnotrema* is illegitimate and *Sistotrema* Pers. is an unavailable earlier homonym of a sanctioned name; both have been synonymised with other legitimate genera. The other six genera have either neuter adjectival or gender uninformative epithets. In some of these generic names, latinised Greek neuter *trema* has been used as an ending analogous to latinised Greek neuter *stoma* (with very similar meanings); e.g., *Lophiotrema* was proposed as a sister genus to *Lophiostoma* (Saccardo 1878: 338–339). Three of the other generic names were created by adding prefixes to *Lophiotrema*.

Four families are typified by genera in this group; these names are formed from Greek neuter linguistic stems, resulting in the termination ***-trema****taceae*.

Antealophiotrema A. Hashim. & Kaz. Tanaka (Hashimoto & al. 2017: 68) [*Pleosporales*]
Type: *Antealophiotrema brunneosporum* (Ying Zhang & al.) A. Hashim. & Kaz. Tanaka

Echinotrema Park.-Rhodes (Parker-Rhodes 1955: 367) [*Hydnodontaceae*]
Type: *Echinotrema clanculare* Park.-Rhodes
Echinotremataceae Jülich (Jülich 1982: 366)

Hydnotrema Link (Link 1833: 298) [*Hydnaceae*], nom. illeg.; ≡ *Sistotrema* Fr. 1821, nom. sanct.
Type: *Hydnotrema confluens* (Pers.) Link; ≡ *Sistotrema confluens* Pers. 1794

Lophiotrema Sacc. (Saccardo 1878: 338) [*Lophiotremataceae*]
Type: *Lophiotrema nucula* (Fr.) Sacc. [a noun in apposition]
Additional spp.: *Lophiotrema alpigenum* (Fuckel) Sacc.; *L. nuculinum* (Rehm) Sacc.; *L. semiliberum* (Desm.) Sacc.; *L. sexnucleatum* (Cooke) Sacc.
Lophiotremataceae K. Hiray. & Kaz. Tanaka (Hirayama & Tanaka 2011: 405)

Neolophiotrema G.C. Ren & K.D. Hyde (Ren & al. 2021: 28) [*Anteagloniaceae*]
Type: *Neolophiotrema xiaokongense* G.C. Ren & K.D. Hyde

Pseudolophiotrema A. Hashim. & Kaz. Tanaka (Hashimoto & al. 2017: 70) [*Pseudolophiotremataceae*]
Type: *Pseudolophiotrema elymicola* A. Hashim. & Kaz. Tanaka
Pseudolophiotremataceae K.D. Hyde & Hongsanan (Hongsanan & al. 2018: 97)

Sistotrema Fr. (Fries 1821: 426, nom. sanct.) [*Hydnaceae*]
Type: *Sistotrema confluens* Pers. 1794, nom. sanct.
Sistotremataceae Jülich (Jülich 1982: 390)

Sistotrema Pers. (Persoon 1794: 108) [*Cerrenaceae*]; legitimate but unavailable (ICN 2018: Art. F.3.4); ≡*Cerrena* Gray (Gray 1821: 649)
Type: *Sistotrema cinereum* Pers.; = *Cerrena unicolor* (Bull.) Murrill (Murrill 1903: 91)

Generic names formed from Latin *trema* (feminine)

Five genera in this group are in *Tremellales* and have species with feminine adjectival epithets. A sixth, *Sclerotrema*, is a monotypic genus in *Auriculariales* but has an etymology explicitly defining *trema* as a reference to tremellaceous fungi; I have corrected its neuter holotype epithet to the feminine form. Two families are typified by genera in this group; these names are formed from Latin feminine linguistic stems, resulting in the termination ***–tremaceae***.

Cuniculitrema J.P. Samp. & R. Kirschner (Kirschner & al. 2001: 155) [*Tremellales*]
Type: *Cuniculitrema polymorpha* R. Kirschner & J.P. Samp.
Cuniculitremaceae J.P. Samp., R. Kirschner & M. Weiss (Kirschner & al. 2001: 155)

Gelidatrema Yurkov, Xin Zhan Liu, F.Y. Bai, M. Groenew. & Boekhout (Liu & al. 2015: 138) [*Tremellales*]
Type: *Gelidatrema spencermartinsiae* (V. de García & al.) Yurkov & al.
Additional sp.: *Gelidatrema psychrophila* M. Tsuji (Tsuji & al. 2018: 69)

Papiliotrema J.P. Samp., M. Weiss & R. Bauer (Sampaio & al. 2002: 875) [*Tremellales*]
Type: *Papiliotrema bandonii* J.P. Samp. & al.
Additional sp.: *Papiliotrema aurea* (Saito) Xin Zhan Liu & al. (Liu & al. 2015: 126)

Rhynchogastrema B. Metzler & Oberw. (Metzler & al. 1989: 281) [*Tremellales*]
Type: *Rhynchogastrema coronata* B. Metzler & Oberw.
"Etym.: Rhynchos (Gr.) – beak, gaster (Gr.) – body, belly, *Tremella*."
Rhynchogastremaceae Oberw. & B. Metzler (Metzler & al. 1989: 283)
"*Rhynchogastremataceae*" (Liu & al. 2015: 125) [an orthographic error]

Sclerotrema Spirin & Malysheva (Malysheva & Spirin 2017: 712) [*Auriculariales*]
Type: *Sclerotrema griseobrunnea* (K. Wells & Raitv.) Spirin & Malysheva [as "*griseobrunneum*"]
"Etymology. 'skleros' (Greek, adj.) – dry, and 'trema' – a reference to tremellaceous fungi, . ."

Sirotrema Bandoni (Bandoni 1986: 668) [*Tremellaceae*]
Type: *Sirotrema pusilla* Bandoni

Genus name in *Microsporidia* (feminine?; neuter?)

Although *Microsporidia* are now categorised as fungi, their names continue to be governed by the International Code of Zoological Nomenclature (ICN 2018: Art. F.1.1).

The etymology of *Systenostrema* identifies the first element *systenos-* as Greek, and the assumption would be that both elements are Greek. However, from the etymology, the authors appear to interpret *-trema* as meaning "thread" (= Greek neuter *nema*). There is nothing in the morphology of the genus that suggests the Greek etymology *-trema*, meaning "opening".

Like the Botanical Code, the Zoological Code requires adjectival epithets to agree with the gender of the genus (ICZN 2000: Art. 31.2). Two of the five *Systenostrema* species have feminine epithets (the other three are gender uninformative), but there is no connection with *Tremella*. The speculation arises that the authors were either treating *-trema* as a "meaningless" feminine suffix (cf. *-ella* and *-opsis*); or that *-trema* was an error for *-nema*, both of which would have required neuter adjectival epithets.

Systenostrema E.I. Hazard & Oldacre (Hazard & Oldacre 1976: 87) [*Microsporidia*]
Type: *Systenostrema tabani* E.I. Hazard & Oldacre
Etymology: "We name this genus *Systenostrema*, meaning "thread tapering to a point" and relating to the polar filament which abruptly constricts to a narrow distal portion."
Additional spp.: *Systenostrema alba* J.I.R. Larss.; *S. candida* J.I.R. Larss. (Larsson 1988: 16)

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Hymenoscyphus conscriptus & *H. fucatus*, newly recorded from Turkey

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Abstract—*Hymenoscyphus conscriptus* and *Hymenoscyphus fucatus* are described as new records from Turkey based on morphological characters and DNA sequence data. Phylogenetic analyses of internal transcribed spacer nuclear ribosomal DNA sequences (nrITS) show that *H. conscriptus* and *H. fucatus* form well-supported clades. *Hymenoscyphus conscriptus* and *H. fucatus* cluster as a highly supported group, closely related to *H. yui* and *H. serotinus,* but represent independent species in the phylogenetic tree; the synonymy of *H. conscriptus* under *H. calyculus* is not supported phylogenetically. Detailed descriptions, illustrations, and discussions concerning morphologically similar and phylogenetically closely related species are provided for each species.

Keywords—*Helotiaceae, Helotiales,* taxonomy

Introduction

The current classification of fungi is still largely based on morphological characters, but DNA sequence analyses of a specific region also help to identify species correctly and determine phylogenetic relationships. Morphological characters (such as apothecial shape and color) are important for distinguishing the families in *Helotiales* (Korf 1973; Wang & al. 2006). However, classifications based on apothecial morphology are not always sufficient, so more studies are required for specifying the taxonomy within the *Helotiales*.

Hymenoscyphus, one of the largest genera of *Helotiaceae,* encompasses some saprotrophic and parasitic species with highly divergent morphological, ecological, and biological characters (Wang & al. 2006; Kirk & al. 2008). *Hymenoscyphus* was established by Gray (1821) and lectotypified with *H. fructigenus* (Bull.) Gray (Dennis 1964). Most *Hymenoscyphus* species have been reported from Europe (Phillips 1887, Dennis 1956, Lizoň 1992), America (White 1943; Dumont 1981a,b; Dumont & Carpenter 1982), and Asia (Thind & Sharma 1980; Sharma 1991; Zhang & Zhuang 2002a,b). About 155 species have been identified in the genus (Kirk & al. 2008) with numerous species recently added (Queloz & al. 2011; Baral & Bemmann 2013; Zheng & Zhuang 2013a,b,c, 2014; Gross & Han 2015; Gross & al. 2015; Kowalski & Bilański 2019; Baral 2019). *Hymenoscyphus* species are normally saprophytic on plant debris, such as wood, twigs, fruits, leaves, and herbaceous stems. They are morphologically characterized by stipitate-cupulate to discoid apothecia; white to yellowish or light-colored hymenial surfaces; more or less long stipes; ectal excipulum typically of textura prismatica (sometimes mixed with textura angularis); fusoid, ellipsoid to scutuloid or ciboroid ascospores; with or without setulae and existence of the remarkable refractive vacuolar bodies in the paraphyses (Dennis 1964, Lizoň 1992, Sharma 1991, Zhang 2002, Kowalski & Bilański 2019).

Some *Hymenoscyphus* species are morphologically difficult to distinguish. making molecular approaches often necessary for taxonomic identification. The internal transcribed spacer of nuclear ribosomal DNA (nrITS) region and a few additional useful regions have been widely used as reliable phylogenetic approaches to determine *Hymenoscyphus* at the species level (Han & Shin 2008; Queloz & al. 2011; Zheng & Zhuang 2013a, 2014, 2015; Baral & Bemmann 2014; Gross & Han 2015; Gross & al. 2015; Kowalski & Bilański 2019; Pastirčáková & al. 2020). For the current study, the ITS region was selected because of availability of universal primers, high PCR success rate, a high percent of correct identification, the considerable number of sequences available in GenBank, and its superior resolution at the infrageneric classification level for the genus. After a macro- and micro-morphological study of the collections and our molecular phylogenetic analyses based on ITS sequences, we concluded that the specimens represent new records for Turkish mycobiota. Sesli & al. (2020) and Çetinkaya & Uzun (2021) reported 14 *Hymenoscyphus* species from Turkey, and *H. conscriptus* and *H. fucatus* are new Turkish records.

Materials & methods

Sampling, macroscopic, microscopic studies

Fresh *Hymenoscyphus* ascomata were sampled from the Bingöl province of Turkey in 2019. The samples were photographed in the field with a Canon (EOS 60D) camera equipped with Tokina 100 mm macro lens. Microscopic characters were observed in both distilled water and IKI solution with a Leica DM500 research microscope under oil immersion. At least 20 ascospores, 20 paraphyses and 15 asci from each studied sample were measured using the Leica Application Suite (version 3.4.0) programme and described based on Hengstmengel (1996), Baral & Bemmann (2013), and Anonymous (2021). The specimens are stored in the Fungarium of Van Yüzüncü Yıl University, Van, Turkey (VANF).

Molecular studies

Fungal genomic DNA was extracted from dried apothecia by following a slightly modified CTAB protocol (Doyle & Doyle 1987). Total genomes were isolated from two specimens as representatives for species *H. conscriptus* and *H. fucatus*. The primer pair N-nc18S10(F) / C26A(R) was used to amplify the ITS region (Wen & Zimmer 1996). All PCR reactions were performed with Thermalcycler (ThermoScientific) under a program consisting of a hot start at 95°C for 4 min, followed by 30 cycles of denaturation at 94 for 1 min, annealing at 54°C for 50 sec, and extension at 72°C for 1 min, with a final elongation step for 5 min. Every reaction was conducted with a negative control containing the mix without template DNA. After checking amplicons in 1% TAE agarose gels staining with Gelred dye, positive reactions were sequenced with forward and reverse primers. The PCR was purified and DNA sequenced in an Applied Biosystems ABI 3730XL automated sequencer. The sequences generated in the study were uploaded to NCBI GenBank Sequence Database.

Finch TV software was used to observe sequence chromatograms. Forward and reverse sequences were aligned to get the correct and reliable sequence for each studied sample. The ITS sequences were trimmed and edited using Molecular Evolutionary Genetics Analysis (MEGA v. 6; Tamura & al. 2013). The obtained DNA sequences were compared by Basic Local Alignment Search Tool (BLAST, https://blast.ncbi.nlm.nih.gov/Blast.cgi) against ITS sequences in the NCBI. Then a combined dataset was prepared comprising the sequences based on the highest scored hits of BLAST search. The ITS sequences of our four *Hymenoscyphus* strains were compared with ITS sequences of 34 other *Hymenoscyphus* strains (from GenBank), which allowed the exact positioning of the new records within the genus *Hymenoscyphus*. The tree was rooted with *Hyaloscypha fuckelii* Nannf. (EU940230) and *Hyaloscypha aureliella* (Nyl.) Huhtinen (EU940228).

The dataset containing multiple sequences was aligned using MEGA. The appropriate model of nucleotide evolution for phylogenetic analyses was determined using the same program, and the model with the lowest BIC (Bayesian Information

Criterion) score was used to describe the best substitution model. Phylogenetic analyses were performed using Maximum Parsimony (MP) in MEGA, and Bayesian Inference (BI) in MrBayes v.3.2 (Ronquist & al. 2012). All positions containing gaps and missing data were eliminated. Initial tree(s) for the heuristic search were automatically obtained by Neighbor-Joining and BioNJ algorithms to a matrix of pairwise distances estimated using the Maximum Composite Likelihood (MCL) approach. After analysis, the tree with superior log likelihood value was selected. The Tree-Bisection-Reconnection (TBR) search method was employed with 100 random addition replications to construct the MP trees and the consensus tree was inferred from the 5 most parsimonious trees. Bootstrap analysis with 1000 repetitions was included to test branch topology (Felsenstein 1985). Bootstrap values lower than 50 % were not given in phylogenetic trees.

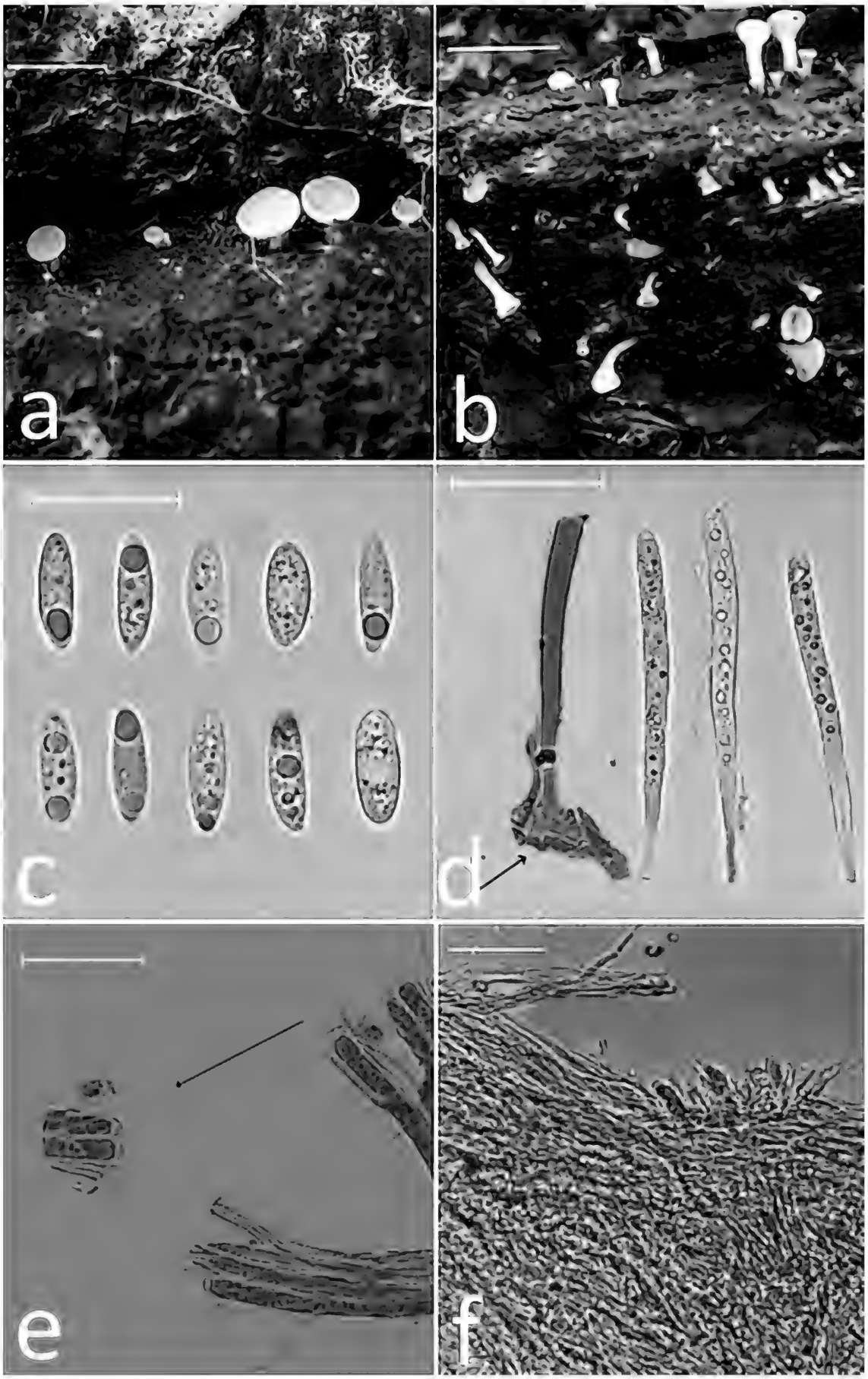
The model test implemented in MEGA showed that the K2+G was the most suitable analysis method. MrBayes was employed to conduct Bayesian phylogenetic analysis using the Markov chain Monte Carlo (MCMC) method under a K2+G model with all the remaining settings set to default (incremental heating scheme of chains, unconstrained branch length, and uninformative topology priors). Markov chains were run for 1,000,000 generations, saving one tree each 1000 generations. A conservative burn-in (25%) was applied after checking for stability on the log-likelihood curves and split variances being <0.01. A majority rule consensus tree of the remaining trees was calculated. Branch support was determined by Bayesian Posterior Probabilities (BPP). The trees were viewed in Figtree v1.3.1. (Rambaut 2010).

Taxonomy

Hymenoscyphus conscriptus (P. Karst.) Korf ex Kobayasi & al.,
Ann. Rep. Inst. Ferment. Res., 1965-66, 3: 55 (1967) Fig. 1

Apothecia 2–3 mm wide, disc or saucer-shaped, individually or in clusters, whitish to yellowish, sometimes blackened at the base. Stipe 2–6 mm long when rehydrated, cylindrical to obconical. Asci [n:15] 110–150 × 7.3–10 µm, cylindric-clavate to cylindric-obconical, 8 spored, apex truncated conical; annulus turning medium blue in IKI, ascus base with croziers. Ascospores [n:20] 13–17 × 4.4–6.2 µm, ellipsoid-cylindrical to obovoid-fusiform, without septa, with several small drops near each end when alive, in dead state with 1-2 large drops due to confluence, without setulae. Paraphyses [n:20] 1.5–4.3 µm wide, cylindrical, uninflated, or slightly lanceolate, never septate

Fig. 1. *Hymenoscyphus conscriptus* (VANF – Acar 1138). a, b. Ascocarp; c. Ascospores in distilled water; d. Asci in distilled water; e. Asci and paraphyses in IKI; f. Ectal excipulum in distilled water. All in dead state, except for apothecia. Scale bars: a, b = 5 mm; c = 20 µm; d–f = 50 µm.


a
b
c
d
e
f

at the apex but are always septate downwards. Ectal excipulum consisting of textura prismatica; hyphae 4–12 µm wide.

Specimen examined: —**TURKEY, Bingöl, Çapakçur stream,** 38.8942°N 40.4792°E, 1150 m, garden area, on branches of *Salix* and *Populus* spp., 24.10.2019, I. Acar 1138 (VANF; GenBank MW959789, MW959790).

Hymenoscyphus fucatus (Cooke & W. Phillips) Baral,
Beih. Z. Mykol. 6: 128 (1985) Fig. 2

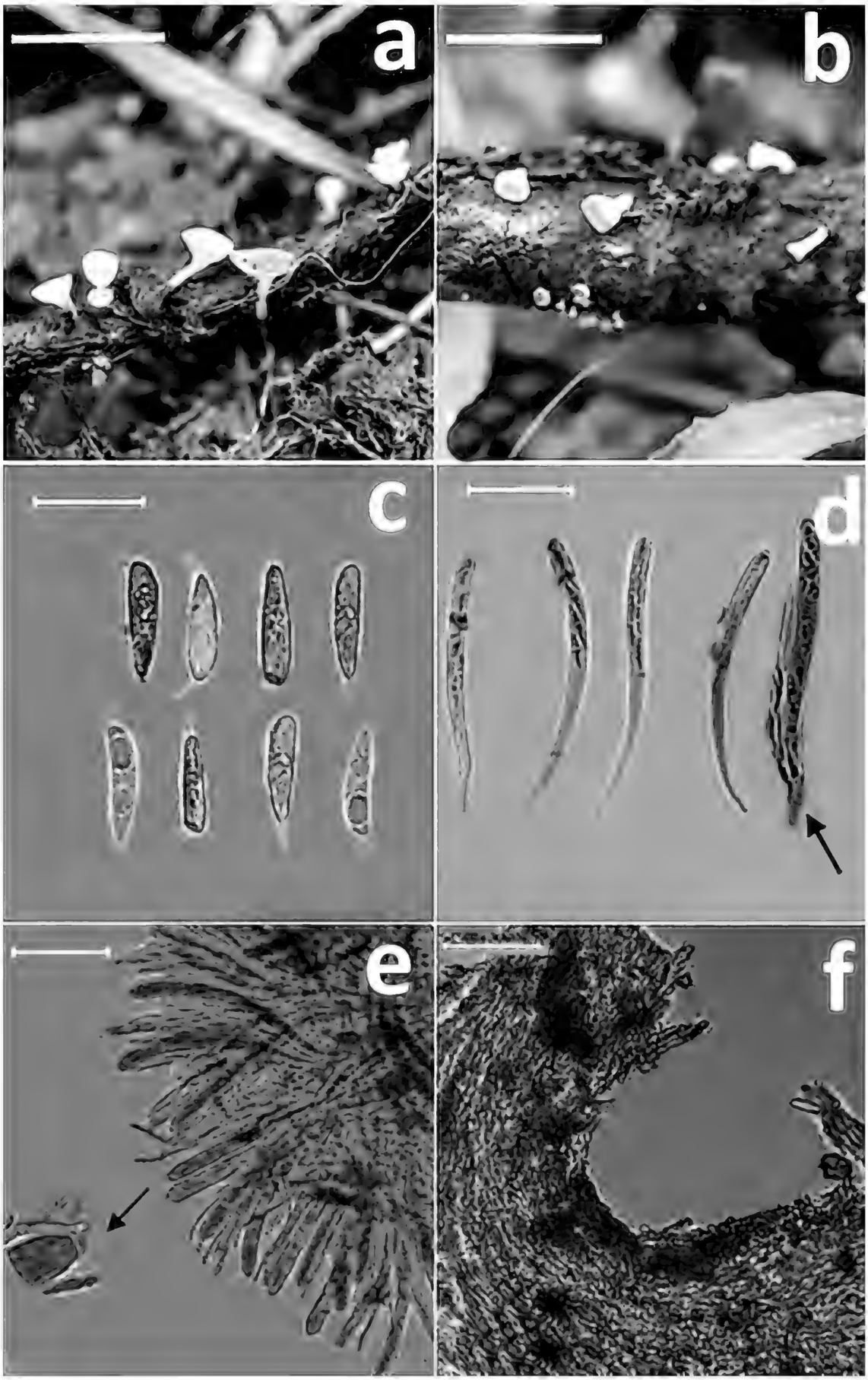
Apothecia 1–2 mm wide, stipitate-cupulate, saucer-shaped, slightly clustered, sparsely mutually grown together at the base, whitish to yellowish, erumpent through (sometimes blackened) epidermis or superficial on delaminated parts of the substratum. Stipe 2–7 mm long when rehydrated, cylindrical to obconical. Asci [n:15] 120–150 × 7–12 µm, cylindric-clavate to cylindric-obconical, 8 spored, ascus base with croziers, apex truncated conical; annulus turning medium blue in IKI. Ascospores [n:20] 19–30 × 4–6.2 µm, ellipsoid-fusiform to obovoid-fusiform, sometimes cylindrical, smooth or slightly curved, guttulate, obliquely biseriate, at apex and base mostly provided with 1–2(–3) µm long, straight or slightly curved setulae. Paraphyses [n:20] 1.5–3 µm diam (slightly wider at the apex), subcylindrical. Ectal excipulum a textura prismatica, hyphae 4–l0 µm diam.

Specimen examined—**TURKEY, Bingöl, Haserek village**, 38.9139°N 40.3133°E, 1624 m, garden area, on stem of plant, 6.11.2019, I. Acar 1149 (VANF; GenBank MW959791, MW959792).

Phylogenetic analysis

The ITS alignment included 40 sequences with 502 nucleotides representing our four new *Hymenoscyphus* strains and 34 *Hymenoscyphus* strains downloaded from GenBank, with two *Hyaloscypha* strains as outgroup. After deleting the unaligned and ambiguously aligned sites, 493 characters remained for analyses, including 92 variants and 72 parsimony informative characters. The MP and BI analyses inferred from the ITS dataset produced similar tree topologies except for minor differences in the arrangement of a few terminal branches. The MP analysis produced five most parsimonious trees (tree length: 294; consistency index: 0.61; retention index: 0.81; rescaled consistency index: 0.53). The phylogram inferred from MP analysis is shown in Fig. 3. Statistical supporting values >50% or >0.50 were shown at the nodes.

Fig. 2. *Hymenoscyphus fucatus* (VANF – Acar 1149). a, b. Ascocarp; c. Ascospores in distilled water; d. Asci in distilled water; e. Asci and paraphyses in IKI; f. Ectal excipulum in distilled water. All in dead state, except for apothecia. Scale bars: a, b = 5 mm; c = 20 µm; d–f = 50 µm.


a
b
c
d
e
f

The phylogenetic tree was divided into three main clades (A, B, C) with moderate bootstrap support and few scattered species. In the tree, our sequences of *Hymenoscyphus conscriptus* and *Hymenoscyphus fucatus* formed moderately supported clusters in clade C with their representatives downloaded from NCBI database (Fig. 3). The DNA sequences from our *Hymenoscyphus conscriptus* specimen showed very high homology with the sequence of MK163877 (an unidentified *Hymenoscyphus* sp.; Pedersen & al. 2020), so that they clustered together without any genetic distance in the phylogenetic tree with 100% bootstrap value (Fig. 3). *Hymenoscyphus conscriptus* appeared to be sister to *H. yui* (KJ472303, KJ472304; Zheng & Zhuang 2015) and *H. serotinus* (DQ431168; Baral & al. 2006, and KM114541; Gross & al. 2015). No nucleotide substitution or indel was detected between *H. conscriptus* and MK163877, but more than twenty-five substitutions were seen among *H. conscriptus, H. yui,* and *H. serotinus.* All of these nucleotide variations were observed in ITS1 and ITS2 subregions. DNA sequences of our *Hymenoscyphus fucatus* specimen presented high homology with the sequence of *Hymenoscyphus fucatus* (JX977147, JX977148; Zheng & Zhuang 2013a). Turkish sequences clustered together with moderate bootstrap and posterior probability values (Fig. 3). Nine nucleotide variations (ITS1 and ITS2) were detected between the Turkish and downloaded *H. fucatus* sequences.

Discussion

Our study shows that combining morphological characters with molecular data is important in identifying a fungus sample to species. The samples collected from Bingöl, Turkey, were determined as *Hymenoscyphus conscriptus* and *Hymenoscyphus fucatus* based on both morphological and molecular characters.

Hymenoscyphus conscriptus and *H. yui* H.D. Zheng & W.Y. Zhuang share very similar macroscopic/microscopic characteristics and sequence data. Apothecia are similar in shape, color, size, asci arising from croziers, the size of its spores. Even though they have very similar characters these two species can be morphologically distinguished the non-guttulate (eguttulate) spores and the ascus apex that is nonamyloid in IKI in *H. yui* (Zheng & Zhuang 2015). *Hymenoscyphus conscriptus* bears guttulate spores, and the apices of its asci are amyloid in IKI. These two species were separated, therefore, based on both macroscopic/microscopic characteristics and sequence data.

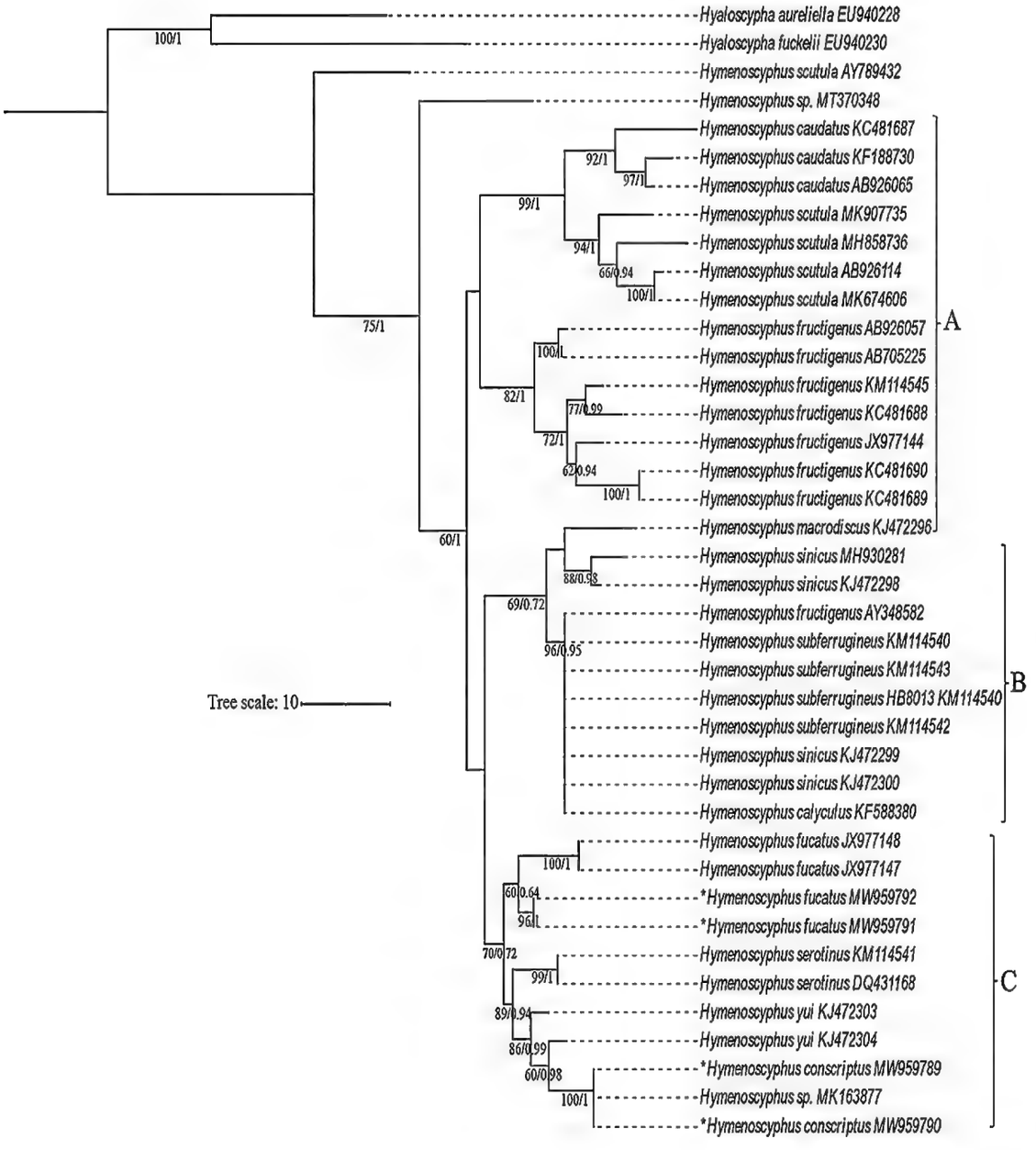


Fig. 3. Maximum Parsimony tree inferred from internal transcribed spacer nuclear ribosomal DNA sequences showing the relationships among *Hymenoscyphus conscriptus*, *Hymenoscyphus fucatus* and related *Hymenoscyphus* species. Statistical support values at nodes are bootstrap values >50% and Bayesian Posterior Probabilities >0.50. Turkish sequences are marked with *.

Hymenoscyphus fucatus shares some similar morphological and molecular characters with *H. serotinus* (Pers.) W. Phillips. Both have similar apothecial shape and color and excipulum structure, but their distinctive stipe and spore structures distinguish them: *Hymenoscyphus serotinus* has an overall pubescent stipe and more scutuloid-curved spores that lack setulae (Baral & Bemmann 2013) while *H. fucatus* lacks pubescence and has setulate spores.

Hymenoscyphus calyculus (Fr.) W. Phillips and *H. scutula* (Pers.) W. Phillips macroscopically similar species could not be easily distinguished when only apothecia and stipe structures were examined. However, paraphyses, habitat, and ascospores are useful and distinctive characters to differentiate them. *Hymenoscyphus calyculus* has septate paraphyses, spores 15–24 × 3–4 µm and it is saprobic on sticks, twigs of hardwoods and broadleaves trees (Breitenbach & Kränzlin 1984; Kuo 2008) while *H. conscriptus* has non-septate paraphyses and smaller spores and grows exclusively on branches and trunks of *Salix* species. *Hymenoscyphus conscriptus* and *H. calyculus* were also distinguished by their ITS sequences and lie within different clades in the phylogenetic tree (Fig. 3).

Hymenoscyphus fucatus and *H. scutula* (Pers.) W. Phillips were considered separate species by Baral (Baral & Krieglsteiner 1985) and Hengstmengel (1996). *Hymenoscyphus fucatus* and *H. scutula* are microscopically similar in apothecial shape and color and ascospore morphology. However, dimensions of apothecia and asci can be used to distinguish the two species. *Hymenoscyphus scutula* has apothecia that are 1–4 mm diam and asci that measure 90–110 × 8–10 µm and lack croziers (Breitenbach & Kränzlin 1984; Uzun & al. 2010); *H. fucatus* has apothecia 1–2 mm and asci measuring 120–150 × 7–12 µm and arising from croziers. The phylogenetic distance *Hymenoscyphus fucatus* is phylogenetically quite distant from *H. scutula* so these species cannot be accepted as synonyms.

Determination of fungi at the species level is still a matter of intensive debate. Limited morphological features and inaccurate description or identification of some taxa are, as in other fungal groups, main problems in the taxonomic studies of *Hymenoscyphus* genus. Future work will improve our knowledge of fungal species diversity and firmly establish a logical generic circumscription. With the aid of integrated studies combining morphology and sequence data, *Hymenoscyphus conscriptus* is supported as an independent species, and it and *H. fucatus* have been confirmed as new records for Turkey.

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First report of *Erysiphe bunkiniana* from Pakistan

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Abstract—During August–September 2018, powdery mildew symptoms were observed on both surfaces of leaves of *Isodon rugosus* in the Abbottabad and Malakand districts of Pakistan. The causal agent was identified as *Erysiphe bunkiniana*, based on its asexual morph and chasmothecia, and its identity was confirmed by molecular data. This is the first Pakistani report of *Erysiphe bunkiniana* and the first sequence obtained for this powdery mildew species.

Key words—*Erysiphaceae, Lamiaceae,* new record, ITS sequence

Introduction

Powdery mildews are biotrophic, often highly specialized pathogens, attacking nearly 10,000 vascular plant species (Braun & Cook 2012). More than one powdery mildew species can parasitize a single host plant species. The 872 species described by Braun & Cook (2012) form a characteristic white, talcum powder-like coating on the surfaces of different host plants, including economically important crops and ornamentals. Accurate identification is essential for effective control; however, these obligate biotrophs pose problems for taxonomists, as many species lack clear morphological characters to distinguish them, are difficult to culture, and therefore require molecular techniques to discriminate between them. The increasing application of molecular methods to the study of powdery

mildews has led to an increasing number of described species (Ellingham & al. 2019). From Pakistan, only 10 genera and 42 species of *Erysiphaceae* are known (Ahmad & al. 1997, Anwar & al. 2020, Riaz & al. 2020, Afshan & al. 2021). Currently, research using morphological and molecular methods is underway to explore this group of fungi. Many new records (as well as new species) are expected in the future.

During 2018, a powdery mildew fungus was collected on leaves of wrinkled-leaf isodon (*Isodon rugosus*) in the districts Abbottabad and Malakand, Pakistan. The infected leaf surfaces were covered with white powdery mycelial masses, conidiophores, conidia, and chasmothecia. After careful morphological and molecular analyses, the fungus was identified as belonging to the genus *Erysiphe*.

Materials & methods

Sample collection

During phytopathological surveys in August–September 2018, we observed powdery mildew infections on leaves of *Isodon rugosus* in the district Abbottabad and Malakand, Khyber Pakhtunkhwa, Pakistan. The infected plants were shade dried on blotting paper and protected in brown envelopes for future research. The specimens were deposited at the herbarium of the University of Peshawar, Khyber Pakhtunkhwa, Pakistan (PUP) and Institute of Botany, University of the Punjab, Lahore, Punjab, Pakistan (LAH).

Morphology

The infected leaves were examined under a Labomed CSM2 stereomicroscope, and slides were prepared in lactic acid. We examined the hyphae on the host, hyphal appressoria, conidia, conidiophores, and chasmothecia (including asci and ascospores) under a Nikon YS 100 microscope. Twenty measurements per structure were recorded using a Lomo Filar Eyepiece Micrometer AM9-2-15x on a Zeiss microscope. Micrographs were made using a HDCE-5X digital camera.

DNA extraction, PCR amplification, phylogenetic analysis

Powdery mildew infections were scraped off fresh fungal specimens with sterile razor blades, ground in liquid nitrogen, and stored in Eppendorf tubes at 18 °C. DNA was extracted using GeneJET Plant Genomic DNA Purification Mini Kit #K0791 according to the manufacturer's instructions. The Internal Transcribed Spacer (ITS) region was amplified using PMITS1/PMITS2 primers (Cunnington & al. 2003) and then commercially sequenced by Tsingke in China. Raw sequence data were edited using BioEdit (Hall 1999). The ITS sequences were BLASTn searched against the GenBank database (www.ncbi.nlm.nih.gov) and aligned using Muscle E multiple alignment tool within MEGA X (Kumar & al. 2018). Forty-two ITS sequences were analyzed using the maximum likelihood (ML) method based on the GTRCAT model

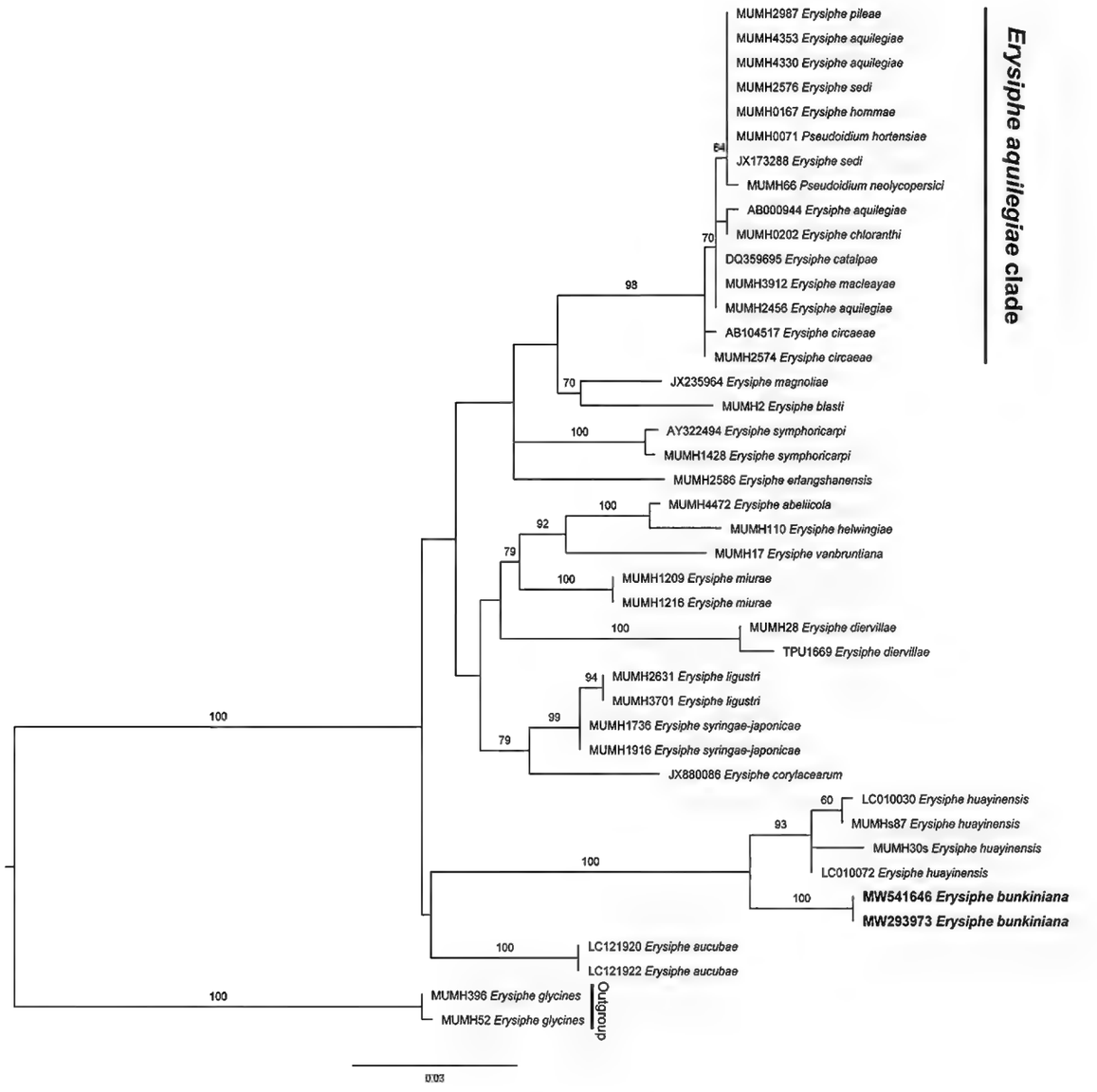

Fig. 1. Phylogenetic analysis of the ITS region for 42 *Erysiphe* sequences, with *Erysiphe glycine* as outgroup. The evolutionary history was inferred by using the Maximum Likelihood method based on the GTRCAT model in RAxML-HPC2. Bootstrap support values >60% are cited on nodes. Amplified sequences of *Erysiphe bunkiniana* from Pakistan are in bold.

in RAxML-HPC2. The final phylogram was visualized in FigTree.v1 4.4. and edited using Adobe Illustrator. After elimination of gaps and missing data, the final dataset comprised 614 positions. *Erysiphe glycine* served as the outgroup. All sequences were aligned and trimmed at conserved sites from both 5′ and 3′ ends.

Phylogenetic results

The final ITS dataset comprised 614 positions, and the phylogenetic tree is shown in Fig. 1; the percentage of trees in which the associated taxa clustered together is shown next to the branches, and the tree is drawn to

scale, with branch lengths measured in the number of substitutions per site. *Erysiphe bunkiniana* (Fig. 1) clusters with *E. huayinensis* (LC010080, LC010072, AB015914, LC010030), with a 95-bootstrap value.

Taxonomy

Erysiphe bunkiniana U. Braun, Feddes Repert. 91(7–8): 441 (1980) Fig. 2

Mycelium amphigenous, mostly epiphyllous, thick, persistent to evanescent, effuse and in white patches; hyphae hyaline, smooth, septate, thin-walled, about 2 µm diam. Hyphal appressoria nipple-shaped to moderately lobed, 4–8 µm diam. Conidiophores arising from upper surface of mother cell, 65–103 × 9–10 µm; Foot cells cylindrical, straight or (sometimes) curved, 13–36 × 6–11 µm, constricted at basal septum, followed by 1–3 shorter cells, forming conidia singly. Conidia ellipsoid-ovoid, doliiform or cylindrical, 24–35 × 11–17 µm, without fibrosin bodies; Germ tubes terminal to lateral, short to moderately long, conidial appressoria somewhat swollen, alobate to lobate, tubes 3–7 µm wide. Chasmothecia scattered to gregarious, globose to subglobose, light to dark brown, 90–129 µm diam.; Peridium cells polygonal, 6–22 µm diam. Appendages numerous, about 6–25 in number, arising in lower half of ascomata, mycelioid, simple, straight or frequently irregularly to subdichotomously branched, 14–173 × 6–11 µm, apex often pointed, rarely obtuse, 0.6–3 times as long as chasmothecial diam., 4–12 µm wide, septate, walls thin, smooth or fairly rough, hyaline or slightly pigmented below. Asci 4–9 per chasmothecium, ellipsoid, obovoid, 42–70 × 30–50 µm, sessile or stalked, 4–8-spored. Ascospores ellipsoid to ovoid, 16–24 × 11–18 µm, colorless or yellowish.

Specimens examined: **PAKISTAN, Khyber Pakhtunkhwa, Malakand Division**, Malakand district, 844 m alt., on *Isodon rugosus* (Wall. ex Benth.) Codd (*Lamiaceae*), 19 September 2018, A. Anwar A#13 (PUP Bot.05; GenBank MW541646); **Hazara Division**, Abbottabad district, Mukshpuri, at 9200 m alt., on *I. rugosus,* 13 August 2018, N.S. Afshan & J. Majeed JP#04 (LAH36140; GenBank MW29397).

Discussion

In the NCBI BLASTn analysis our ITS sequences (MW541646 and MW293973) showed 97% identity with *Erysiphe huayinensis* R.Y. Zheng & G.Q. Chen (LC010080.1), having 99% query coverage and 0.0 E. value. Sequences of different *Erysiphe* taxa were obtained from GenBank to determine the phylogenetic position of the sample. A few gaps were deleted from the final file to get the optimal alignment for phylogenetic analysis. The aligned data set included 614 sites of which 455 were conserved, 155 were

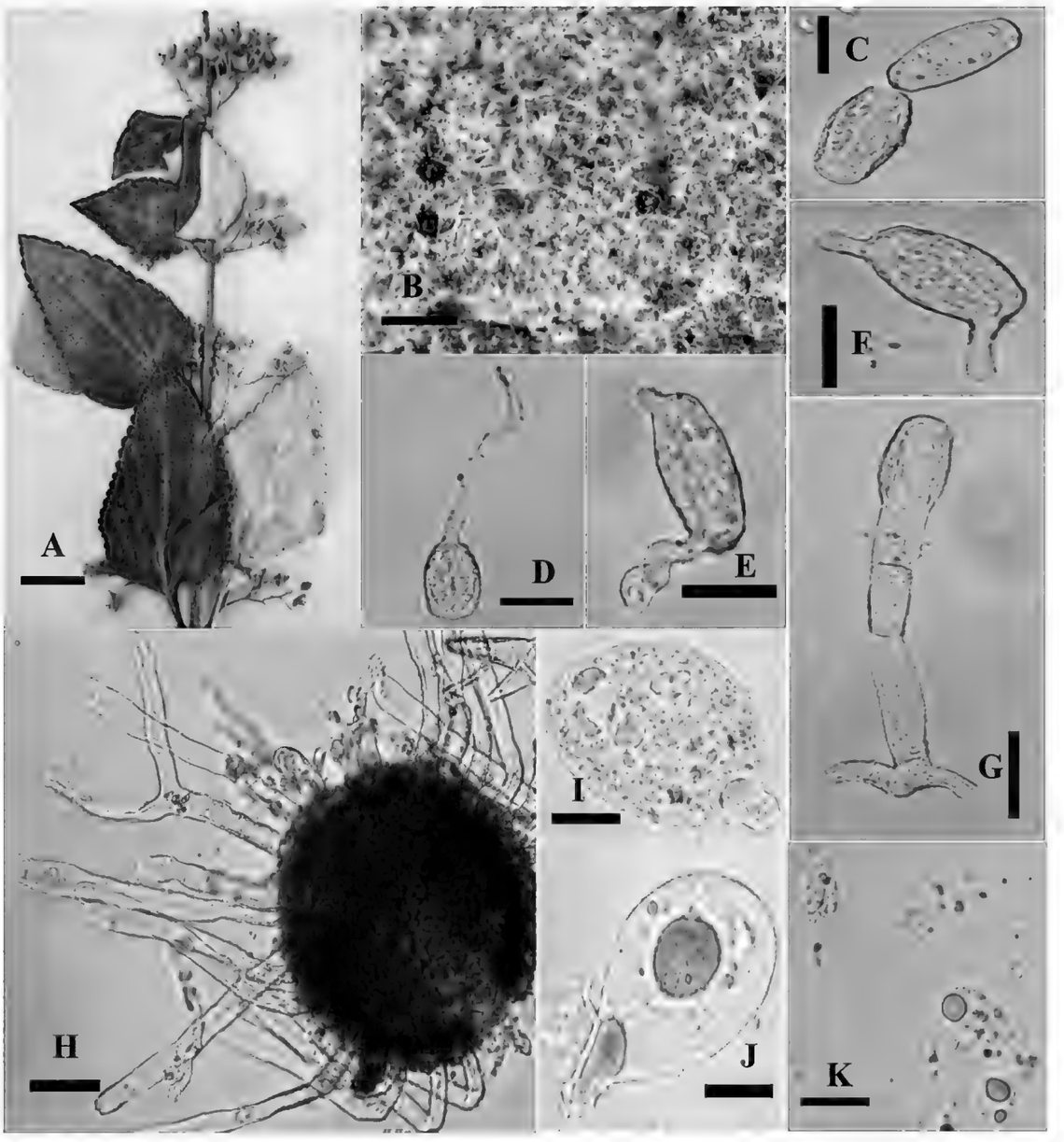

Fig. 2: *Erysiphe bunkiniana* (PUP Bot.05): A. Infected host plant, *Isodon rugosus*; B. Fungal mycelium under stereomicroscope; C. Conidia; D–F. Germinating conidia; G. Conidiophore; H. Chasmothecium; I, J. Asci with ascospores; K. Ascospores. Scale bars: A = 20 mm, B = 2 mm, C–F, I, J = 15 µm, G, K = 20 µm, H = 30 µm.

variable, and 133 were parsimony informative. All ambiguously aligned gaps in the final aligned dataset were treated as 'missing'.

In the phylogram, the new sequences retrieved from *Erysiphe* on *Isodon rugosus* (Fig. 1) cluster with *E. huayinensis* sequences (LC010080, LC010072, AB015914, LC010030) with a 93-bootstrap value. Morphologically, our

species agrees well with *Erysiphe bunkiniana* (Braun & Cook 2012), but we could not find any sequence data of this species in GenBank. Based on the morphological compliance of the Pakistani collections on *Isodon rugosus* with *E. bunkiniana* and the obvious sequence difference from *E. huayinensis*, which may also occur on *Isodon* spp., the identification of our powdery mildew specimens as *Erysiphe bunkiniana* is reasonable. Furthermore, *E. huayinensis* is well differentiated from *E. bunkiniana* morphologically by smaller ascomata and appendages that become thick-walled in the lower half. The apices of the appendages are often enlarged to subclavate (Braun & Cook 2012).

Erysiphe bunkiniana has previously been reported on *Isodon* spp. (*Lamiaceae*) from Asia (China, India, Russian Far East) (Fungus-Host Database https://nt.ars-grin.gov, 29 March 2021; Braun & Cook 2012). According to Liu & Braun (2009), it is difficult to distinguish *E. bunkiniana* from *E. rabdosiae* R.Y. Zheng & G.Q. Chen as these taxa were previously separated only based on the length of the chasmothecial appendages and the number of ascospores. According to Braun & Cook (2012), *E. rabdosiae* represented collections of *E. bunkiniana* with less developed appendages. *Erysiphe bunkiniana* is a new record for Pakistan, and this is the first Pakistani report of any powdery mildew on *Isodon rugosus*. Finally, the *E. bunkiniana* sequences obtained during the current research represent the first for this species.

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Six *Typhula* spp. newly recorded from Türkiye

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Abstract—Macrofungi samples were collected during routine field studies in 2019 within the borders of Hakkari and Şırnak provinces, Türkiye. Six *Typhula* species were collected for the first time from Türkiye: *T. corallina*, *T. crassipes*, *T. incarnata*, *T. micans*, *T. phacorrhiza*, and *T. quisquiliaris*. Detailed descriptions of the species are presented with morphological and microscopic illustrations and ecological information.

Key Words—*Agaricales, Typhulaceae,* taxonomy

Introduction

Typhula (Pers.) Fr. has clavarioid basidiocarps that arise from sclerotia or directly from mycelia, typically with amyloid spores and dextrinoid hyphae (Ikeda & al. 2015, Olariaga & al. 2016). Characters that delimit *Typhula* from other clavarioid genera are small basidiomata, often with a corticate stipe and the presence of caulinar hairs or gelified hyphae (Olariaga & Salcedo 2009).

Typhula species produce fruitbodies that are slender, filiform, or clavarioid and white, yellow, pink, brownish, or reddish (Kaygusuz &

Çolak 2017). Typhuloid fungi are one of the taxonomically most under-researched groups of *Basidiomycota*, likely because their tiny basidiomata are overlooked by mycologists (Olariaga & al. 2016).

According to the online databases (http://www.indexfungorum.org and https://www.mycobank.org), around 80 *Typhula* species have been described worldwide. In Türkiye, five species—*T. erythropus* (Pers.) Fr., *T. fistulosa* (Holmsk.) Olariaga, *T. juncea* (Alb. & Schwein.) P. Karst., *T. spathulata* (Corner) Berthier, *T. setipes* (Grev.) Berthier—have been identified by previous researchers (Solak & al. 2007, Sesli & al. 2016, Kaygusuz & Çolak 2017, Uzun & al. 2017, Işık 2020).

The current Turkish checklist (Sesli & al. 2020) and recent studies (Berber & al. 2021, Acar & al. 2021, Sesli 2021, Uzun 2021a,b, Şelem & al. 2021, Çetinkaya & Uzun 2021, Akata & al. 2021, Altuntaş & al. 2021) do not report *T. corallina*, *T. crassipes*, *T. incarnata*, *T. micans*, *T. phacorrhiza*, and *T. quisquiliaris*, which are cited here as new records for the mycobiota of Türkiye.

The study aims to present new distribution localities for *Typhula* species and contribute to the macrofungal diversity of Türkiye.

Materials & methods

Fresh basidiomata of *Typhula* species were collected from Hakkari and Şırnak provinces, Türkiye, during field studies in 2019. Collected specimens were photographed in situ using a Canon (EOS 60D) camera equipped with Tokina 100 mm macro lens. Macromorphological characters were recorded based on field notes and coloured photographs of fresh fruiting bodies. Micro-morphological characteristics of dried specimens were examined after sectioning and rehydration. Microscopic observations were made using a Leica DM500 research microscope. Micrographs were captured with a Leica ICC50 HD camera and measured with Leica Application Suite (version 3.4.0). The reagents 5% KOH and iodine (IKI) were used as investigation media. At least 30 spores and 15 basidia from six samples in distilled water and KOH were measured for each recorded species. The specimens were identified after consulting the literature (Remsberg 1940, Corner 1950, Berthier 1976, Breitenbach & Kränzlin 1986, Hansen & Knudsen 1997, Wojewoda 2000, Olariaga & Salcedo 2005, Buczacki & al. 2012, Olariaga & al. 2020). Collected samples were deposited as voucher specimens in Fungarium of Van Yüzüncü Yıl University, Van, Türkiye (VANF).

Taxonomy

Typhula corallina Quél., C.r. Assoc. Franç. Avancem. Sci. 11: 396 (1883) Fig. 1

Sporophores 0.5–8 mm long, more or less curved, usually tapering towards the tip (some tips lanceolate), without hairs, whitish in color, with a slightly delimited stipe and clavula; clavula 0.5–5 mm long, cylindrical to narrowly claviform, with obtuse to acute apex. Stipe 0.5–3 mm long, cylindrical, straight, or curved, glabrous, one to 6–7 sporophores developing from a single sclerotium. Sclerotia 0.5–2 mm diam., lobed, ovoid to irregular, with a smooth surface, ocher to reddish-brown, dark brown to blackish when dry, gel-like inside, rarely absent.

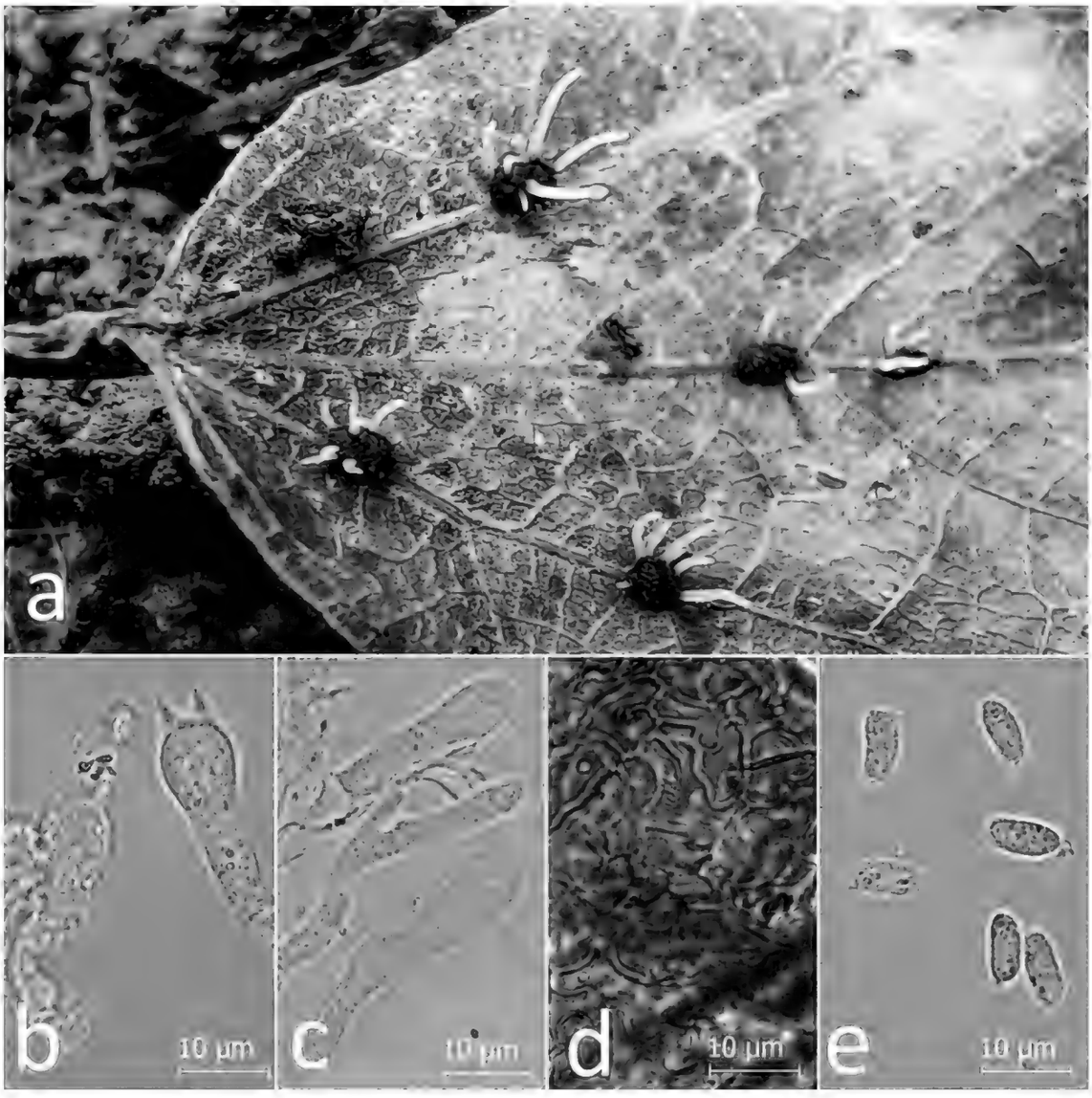

Fig. 1. *Typhula corallina* (VANF 7883):
a. Basidiomata; b. Basidia; c. Basidioles; d. Epidermoid cells of sclerotium; e. Basidiospores.

Basidiospores 6–10 × 4–5 µm, elongated ellipsoid, smooth, hyaline, thin-walled, with an ambiguous apiculus. Basidia 26–38 × 6.5–9 µm, clavate, with 2–4 sterigmata, without basal clamp.

Specimens examined—**TÜRKIYE, Hakkari, Central district,** neighborhood of Merzan, 37.5699°N 43.7217°E, 1791 m, on leaf remnants of *Populus* sp., 14.07.2019 Kesici (VANF 7883); **Durankaya town**, 37.5554°N 43.6174°E, 1693 m, on remains of *Xanthium strumarium* L., 03.11.2019 Kesici (VANF 7884).

Habitat: Usually growing gregariously on very diverse decaying plant remains such as herbaceous stems, horsetail ferns (*Equisetum* sp.) and leaves (Corner 1950, Berthier 1976).

Comments—Although the basidiospores of the collections cited above are very close to the description of Olariaga & Salcedo (2005), they are larger than those cited by Corner (1950) and Requejo & Castro (2015). Berthier (1976) stated that sometimes there is no sclerotium; similarly we did not find sclerotia in some of our specimens.

Macroscopically, *T. corallina* is characterized by its sporophores with undifferentiated stipe and clavula that are usually fasciculate or aggregated. Microscopically, the absence of clamps and differentiated hairs on the stipe are useful characters in its identification. Sporophores of *T. crassipes*, which are also aggregated and glabrous, are distinguished by yellowish to light-brown sclerotia and relatively longer sporophores (Corner 1950, Berthier 1976, Olariaga & Salcedo 2005).

Typhula crassipes Fuckel, Jb. Nassau. Ver. Naturk. 23–24: 32 (1870) Fig. 2

Sporophores 2–15 mm long, filiform, unbranched, straight or often curved to form a hook shape, equal or somewhat tapering towards the tip, without hairs, whitish in color, with a slightly delimited stipe and clavula, clavula 2–10 mm long, smooth, cylindrical to club-shaped, blunt at tip. Stipe 0.5–5 mm long, indistinct, cylindrical, glabrous, usually more than one sporophore (≤10–11) develop from a single sclerotium. Sclerotia 1–3 mm diam., on or embedded in substrate, ovoid to irregular, with a smooth surface, pale ocher to light-brown, gel-like inside, rarely absent.

Basidiospores 6–10.5 × 4.5–6 µm, elongated ellipsoid, smooth, hyaline, thin-walled, with an ambiguous apiculus. Basidia 25–40 × 7–9 µm, clavate, with 2–4 sterigmata, without basal clamp.

Specimen examined—**TÜRKIYE, Şırnak, Uludere district,** formerly Hilal town, 37.2827°N 42.4650°E, 1017 m, on branch remnants of *Rubus idaeus* L., 15.11.2019 Kesici (VANF 7885).

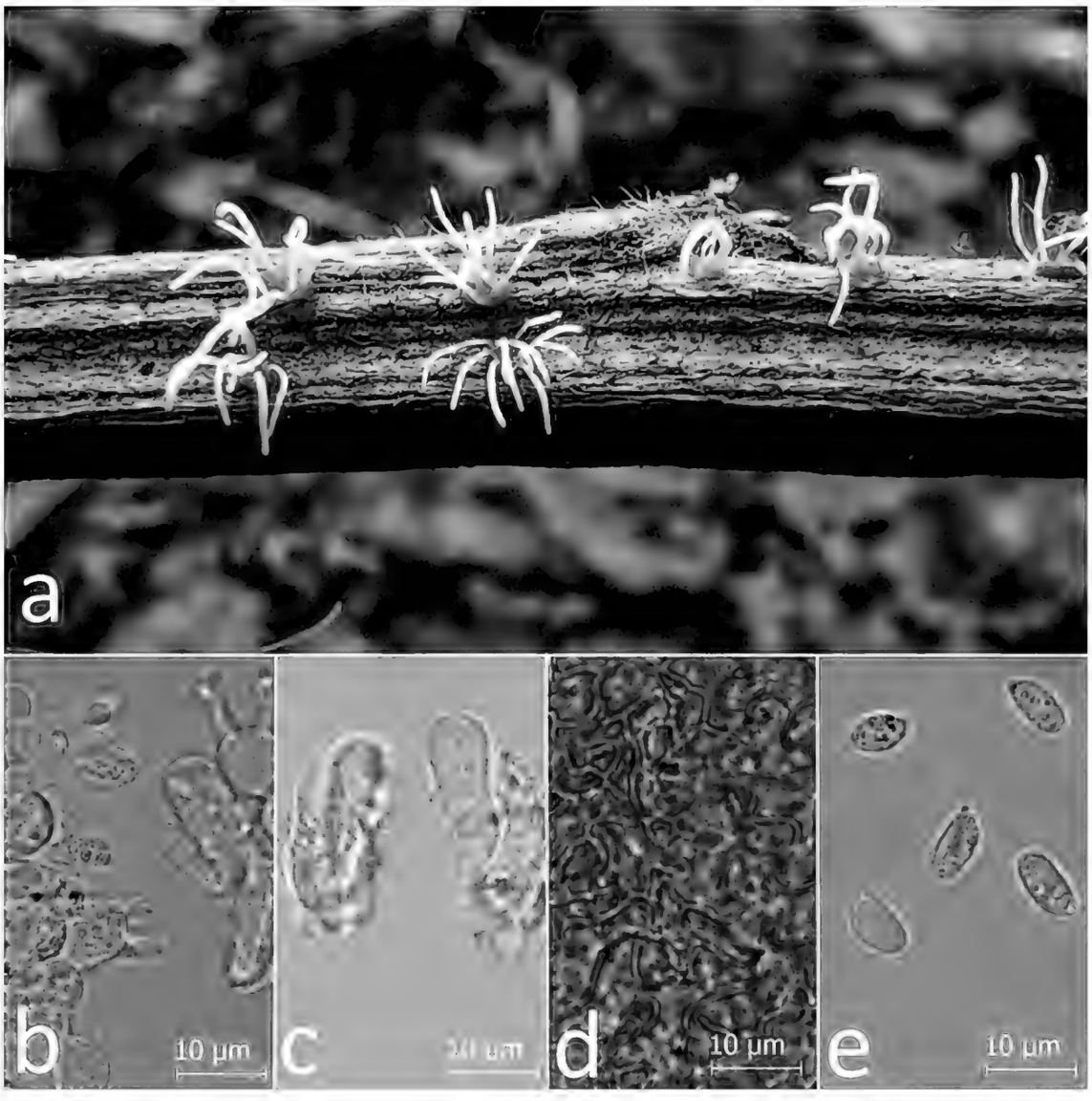

Fig. 2. *Typhula crassipes* (VANF 7885):
a. Basidiomata; b. Basidia; c. Basidioles; d. Epidermoid cells of sclerotium; e. Basidiospores.

Habitat: Grows usually gregariously on dead, fallen and rotting leaves and herbaceous stems (Buczacki & al. 2012, Hansen & Knudsen 1997).

Comments—The ecological and morphological characteristics of the collection above agree with Hansen & Knudsen (1997) and Buczacki & al. (2012). Although macroscopically similar to *Typhula corallina, T. crassipes* is distinguished by its sclerotia that are lighter in color and often embedded in the substrate, a greater number of sporophores developing from a single sclerotium, and relatively longer sporophores (Buczacki & al. 2012, Hansen & Knudsen 1997).

Typhula incarnata Lasch ex Fr., Epicr. Syst. Mycol.: 585 (1838) Fig. 3

Sporophores 5–35 mm long, filiform, unbranched, straight, or slightly curved towards to tips, with a clear separation between stipe and clavula, clavula 5–10 mm long, distinctly pink, smooth, slightly wider than the stipe, cylindrical to club-shaped, blunt at tip. Stipe 5–30 mm long, filiform, short hispid especially towards to bottom, whitish with pink tinge becoming pale brown, one or more (usually one) sporophore arising from each sclerotium. Sclerotia 1–3 mm diam., on surface of the host, rounded to oblong, with a smooth surface, pale brown to hazel-brown, partially gel-like inside.

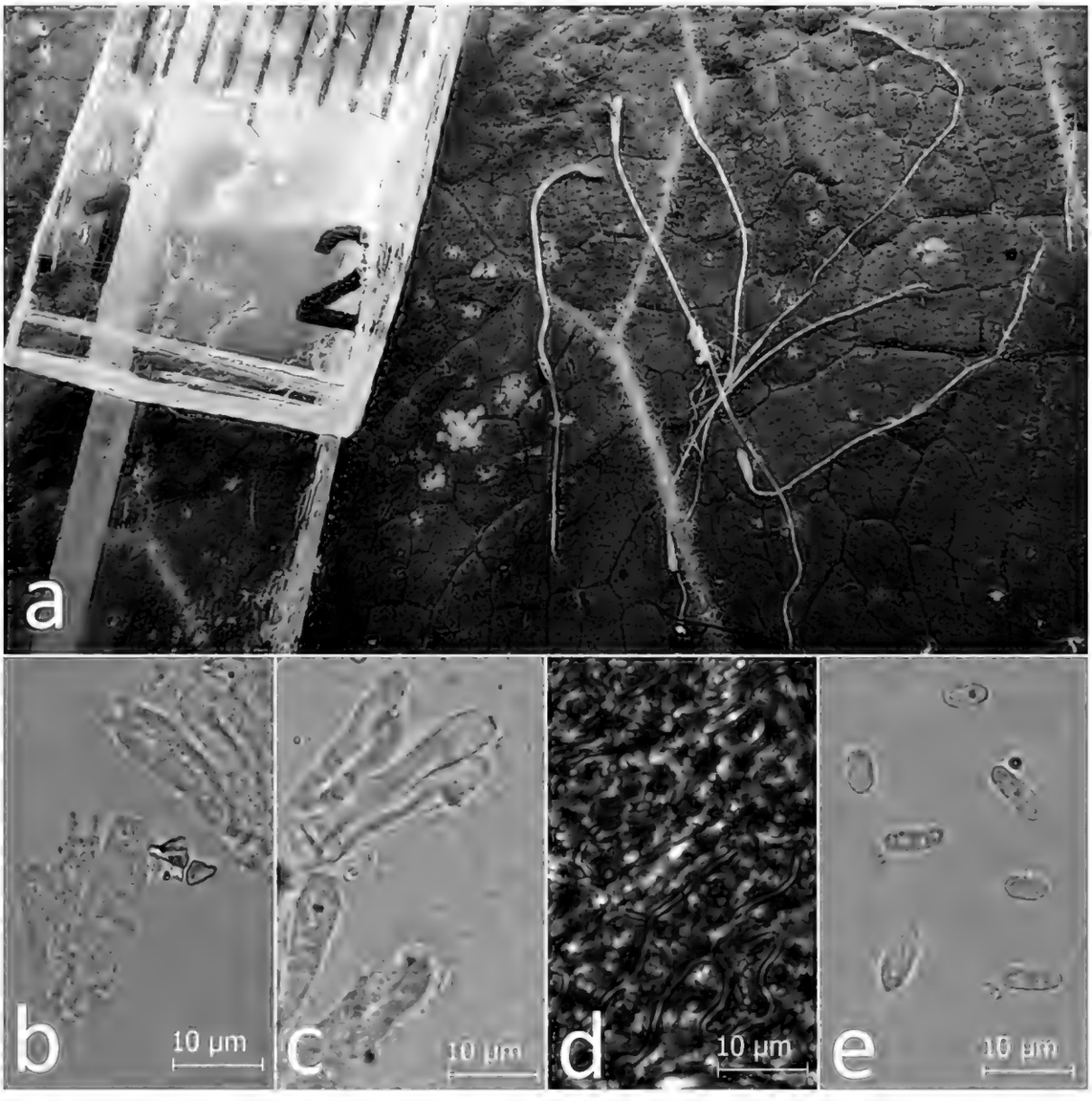

Fig. 3. *Typhula incarnata* (VANF 7886):
a. Basidiomata; b. Basidia; c. Basidioles; d. Epidermoid cells of sclerotium; e. Basidiospores.

Basidiospores (6–)7–11 × 3–5 µm, elongated ellipsoid, flattened on one side above a pointed apiculus, smooth, hyaline, thin-walled, weakly amyloid. Basidia 25–35 × 4–7 µm, narrowly clavate, with 2–4 sterigmata.

Specimen examined—**TÜRKIYE, Hakkari, Central district,** neighborhood of Merzan, 37.5699°N, 43.7219°E, 1791 m, on decaying plant remains, 26.10.2019 Kesici (VANF 7886).

Habitat: Grows solitary or in small troops on dead grass leaves in late autumn; parasitic on natural and cultivated grasses and cereals, causing "grey snow mold" (Buczacki & al. 2012, Hansen & Knudsen 1997).

Comments—While basidiospores of the collection cited above agree in size with those cited by Hansen & Knudsen (1997); they are slightly larger than the measurements given by Berthier (1976), Corner (1950) and Hoshino & al. (2004). *Typhula graminum* P. Karst., which also parasitizes and causes disease on a variety of herbaceous plants, produces completely white sporophores and lacks pinkish tones. Although *T. micans* sporophores do have pinkish colors, the absence of a sclerotium easily distinguishes it from *T. incarnata* (Remsberg 1940, Buczacki & al. 2012, Hansen & Knudsen 1997).

Typhula micans (Pers.) Berthier, Bull. Mens. Soc. Linn. Lyon 45: 172 (1976) Fig. 4

Sporophores 1–3 mm long, filiform, unbranched, very soft and fragile, pink to lilaceous, separation between stipe and clavula obvious; clavula 0.5–2.5 mm long, cylindrical to slightly irregular, usually circular in cross-section, blunt at tip, smooth or finely floury under magnifying glass. Stipe very short, rudimentary but evident and distinct from clavula. Sclerotia absent.

Basidiospores 8.5–11 × 5–6.5 µm, ellipsoid to ovoid, with an ambiguous apiculus, smooth, hyaline, thin-walled, amyloid. Basidia 30–45 × 5–8 µm, slenderly clavate, with 2–4 sterigmata, basal clamp present.

Specimen examined—**TÜRKIYE, Hakkari, Çukurca district,** Köprülü village, 37.5699°N 43.7219°E, 1791 m, on decaying plant remains, 26.10.2019 Kesici (VANF 7887).

Habitat: Grows solitary or in small troops on rotting herbaceous stems in autumn (Buczacki & al. 2012, Hansen & Knudsen 1997).

Comments—Basidiospores of the specimens cited above are slightly shorter than cited by Buczacki & al. (2012) and Hansen & Knudsen (1997). *Typhula micans* differs from *T. incarnata* (also with pinkish sporophores) which is distinguished by the presence of a sclerotium. *Typhula uncialis* (Grev.)

Berthier, which also does not form a sclerotium and is similar in appearance to *T. micans,* can be distinguished by its white sporophores and shorter spores (Berthier 1976, Buczacki & al. 2012, Hansen & Knudsen 1997).

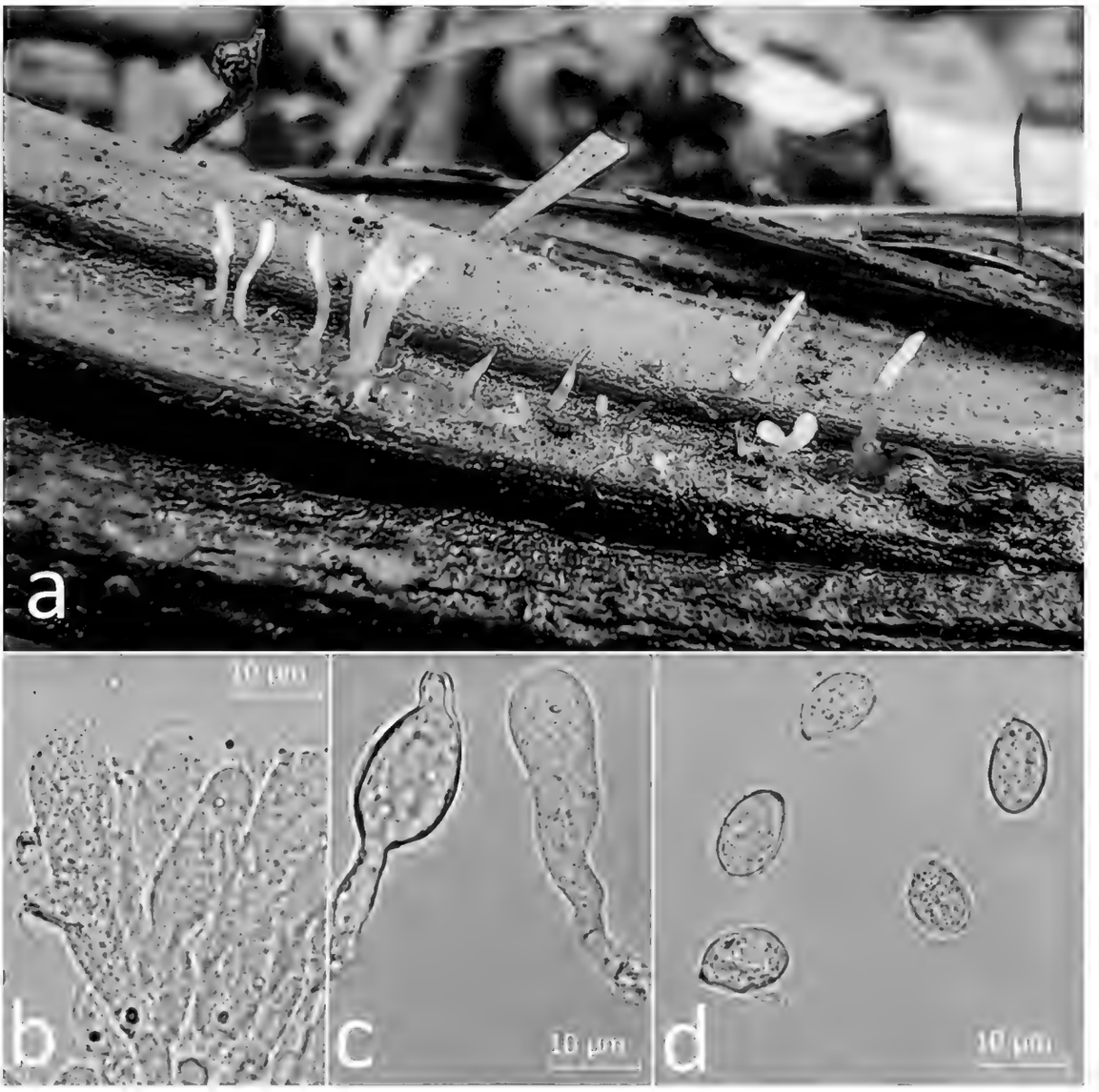

Fig. 4. *Typhula micans* (VANF 7887):
a. Basidiomata; b. Basidia; c. Basidioles; d. Basidiospores.

Typhula phacorrhiza (Reichard) Fr., Observ. Mycol. 2: 298 (1818) Fig. 5

Sporophores 20–95 × 0.5–1 mm, filiform, elastic, tough, straight or slightly curved, somewhat branched, apex usually acute, tapering below into a long filiform stipe, distinguishing between stipe and clavula is difficult except at maturity, translucent when young, later honey brown to reddish-brown, somewhat darker towards to apex, upper third smooth and fertile,

under third and also blunt tips sterile, pubescent at the bottom, one or more growing from any point on the sclerotium, sometimes arising directly from the mycelium. Sclerotia 2–5 × 0.5–1 mm, lobed and irregular disc-shaped, cinnamon-brownish, smooth at first, then wrinkled, gel-like inside, sometimes 2–3 sporophores developing from a single sclerotium.

Basidiospores 10–14 × 5–7 µm, elongated ellipsoid, smooth, hyaline, thin-walled, with an unsharp apiculus. Basidia 17–24 × 7.5–9 µm, clavate, with 2-4 sterigmata, basal clamp absent. Caulocystidia 20–35 × 4–7 µm, clavate to cylindrical, hyaline, somewhat branched.

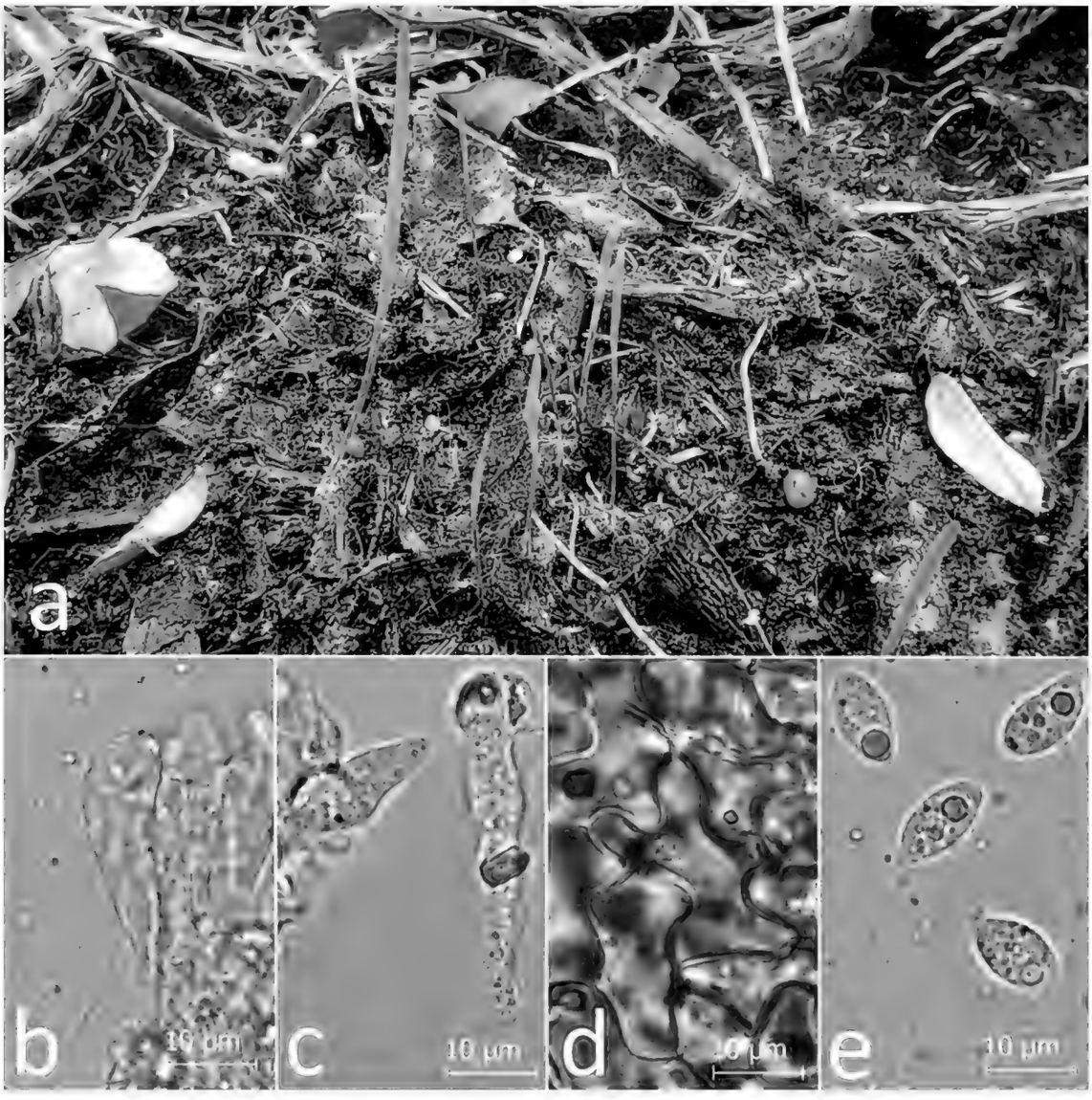

Fig. 5. *Typhula phacorrhiza* (VANF 7888): a. Basidiomata; b. Basidia; c. Caulocystidia; d. Epidermoid cells of sclerotium; e. Basidiospores.

Specimen examined—**TÜRKIYE, Hakkari, Central district,** neighbourhood of Merzan, 37.5699°N 43.7216°E, 1790 m, on rotten wood, 26.10.2019 Kesici (VANF 7888).

Habitat: Grows in clusters or groups on decaying leaves of varied broad-leaved trees in autumn (Breitenbach & Kränzlin 1986).

Comments—The sporophore length is given as 20-100 mm by Breitenbach & Kränzlin (1986) and 40-120 mm by Buczacki & al. (2012) and Hansen & Knudsen (1997), and the basidiospores of the specimens cited above are slightly shorter than the basidiospores in those three studies. *Typhula phacorrhiza* is morphologically very similar to *T. juncea*, but *T. juncea* does not have sclerotium and its spores are smaller (Breitenbach & Kränzlin 1986).

Typhula quisquiliaris (Fr.) Henn., Bot. Jahrb. Syst. 23: 288 (1896) Fig. 6

Sporophores 3–10 mm long, clavate to capitate or almost cylindrical, unbranched, whitish, arising from a sclerotium lying in the pith of the stem, stipe and clavula distinction is evident, clavula 2–6 mm long, ≤3 mm wide, clavate to capitate, usually circular in cross-section, blunt at tip, quite solid, smooth. Stipe 2.4–2.6 mm long, ≤1.5 mm wide, translucent whitish, finely pubescent. Sclerotia 2–3 mm long, ≤0.5 mm thick, yellowish to light brown, not gelatinized within. Scattered in rows along the ribs of the stems or longitudinal fissures, a single sporophore arising from each sclerotium.

Basidiospores 8.5–12 × 4–5.5 µm, ellipsoid to cylindrical, flattened on one side above a pointed apiculus, smooth, hyaline, thin-walled, amyloid. Basidia 35–55 × 6–8 µm, slenderly clavate, with 4 sterigmata, basal clamp present.

Specimen examined—**TÜRKIYE, Hakkari, Central district,** Durankaya town, 37.5549°N 43.6179°E, 1683 m, on rotten remains of *Urtica dioica* L., 03.11.2019 Kesici (VANF 7889).

Habitat: Grows usually gregariously on the dead stems and petioles of various herbaceous plants, especially on *Pteridium* species, in autumn. (Breitenbach & Kränzlin 1986, Wojewoda 2000, Buczacki & al. 2012, Hansen & Knudsen 1997).

Comments—The ecological and morphological characteristics of the Turkish specimens agree with Hansen & Knudsen (1997) and Buczacki & al. (2012). *Typhula quisquiliaris* may be confused with *T. uncialis* (also growing on dead herbaceous stems) and the similar-appearing *T. spathulata.* However, *T. uncialis* has no sclerotia and its spores are smaller and non-amyloid.

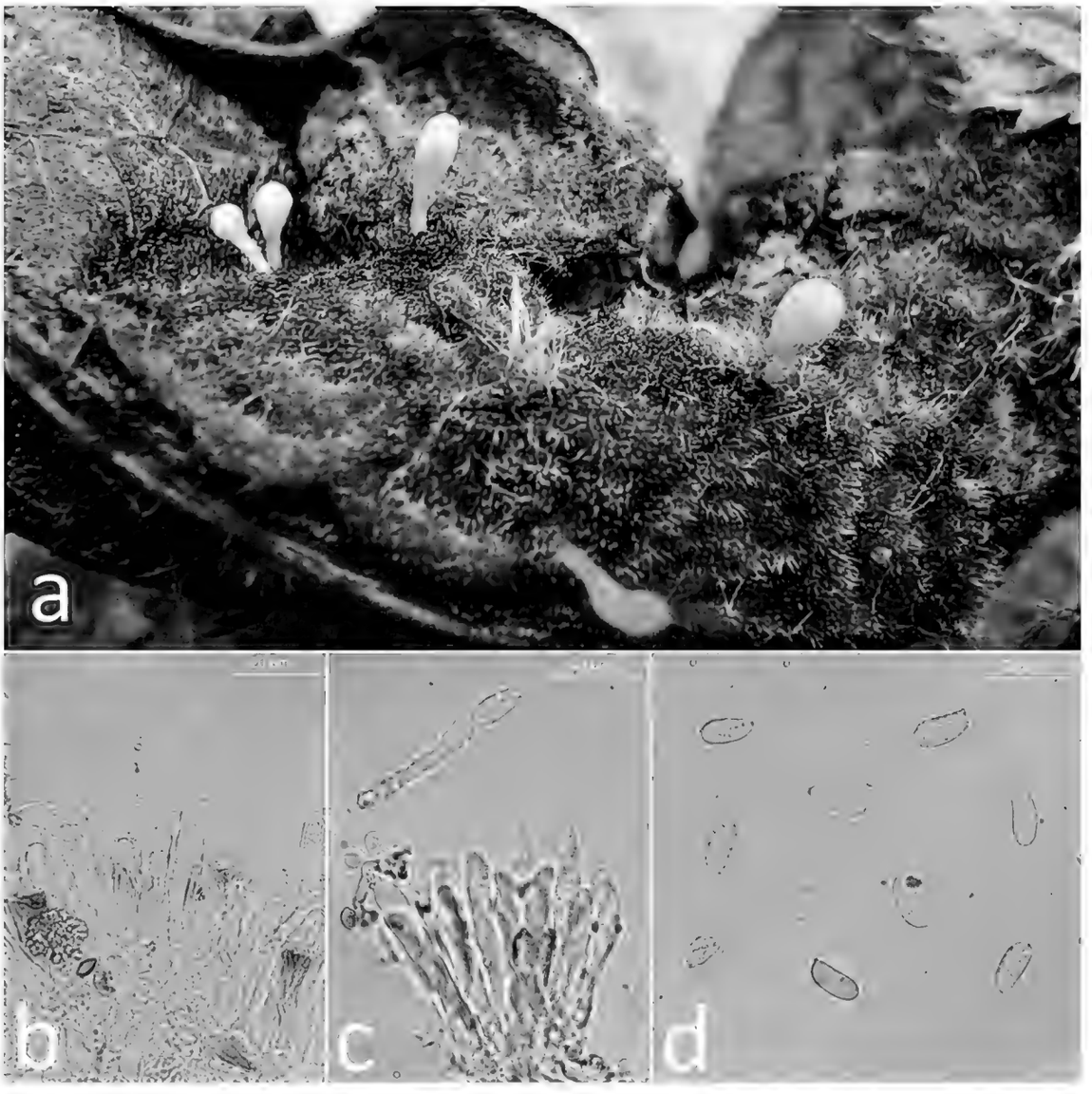

Fig. 6. *Typhula quisquiliaris* (VANF 7889):
a. Basidiomata; b. Basidia; c. Basidioles; d. Basidiospores.

T. spathulata is distinguished by its solitary growth on the ground or amongst moss and absence of clamps (Breitenbach & Kränzlin 1986, Wojewoda 2000, Buczacki & al. 2012, Hansen & Knudsen 1997).

Discussion

This study was conducted in one of the least studied areas of Türkiye in terms of macrofungi, and these areas have significant potential in determining the macrofungal diversity of Türkiye, which is well below the expected level. With our new records, the number of *Typhula* species reported from Türkiye is raised to eleven.

Acknowledgments

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First lichenicolous records of *Chaetopyrena penicillata*

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Abstract—*Chaetopyrena penicillata* is reported for the first time as a lichenicolous fungus. A culture and a sequence were obtained from material growing on *Xanthoria parietina*. Features of the culture on PDA and MEA, the ecology and geography, and the phylogenetic position within *Didymellaceae* based on an ITS sequence are given. A key to the lichenicolous coelomycetes with setose pycnidia is also provided.

Key words—coelomycete, *Pleosporales*, setose fungi, Southern Ukraine

Introduction

The lichenized fungus *Xanthoria parietina* (L.) Th. Fr. is a fine model for the study of the diversity and ecology of lichenicolous fungi (Etayo & Berger 2009, Fleischhacker 2011, Braun & al. 2016, Khodosovtsev & Darmostuk 2016, Tsurykau & Etayo 2017). In 2016, we collected *Pyrenochaeta*-like specimens on apothecia of corticolous *Xanthoria parietina* for testing their growth in culture. Surprisingly, we found a fungus with ampulliform conidiogenous cells and large bacilliform conidia that represented neither *Pyrenochaeta xanthoriae* Diederich (Diederich 1990) nor *Pyrenochaetopsis* Gruyter & al. (de Gruyter & Boerema 2002). Instead, morphological, cultural, and molecular data allowed

us to identify the fungus as *Chaetopyrena penicillata*. Further research has revealed the presence of this species on *Peltigera rufescens* (Weiss) Humb. and *Physcia stellaris* (L.) Nyl.

Chaetopyrena Pass. is a poorly studied asexual genus, and its phylogenetic position in *Didymellaceae* has only recently been identified (de Gruyter & al. 2010). No modern description of the genus was provided in Hyde & al. (2013), nor are any molecular data available from the generic type, *Chaetopyrena hesperidum* Pass., described from *Citrus* (Hyde & al. 2013). Only one *Chaetopyrena* species, *C. penicillata*, has been isolated in culture for which ITS and LSU sequences have also been obtained (Arzanlou & Khodaei 2012; Wang & al. 2016). In this paper, we report for the first time a species of *Chaetopyrena* with a lichenicolous habit and provide a full description, cultural characteristics, and ITS sequence data.

Material & methods

Morphological observations and isolation

The material was examined using standard microscopic techniques. Sections for anatomical examination were cut by hand and studied microscopically in water preparations. Measurements were made in water with an accuracy of 0.2 µm for conidia, conidiogenous cells, cell walls and hyphae; of 5 µm for the pycnidial wall; and of 10 µm for conidiomata. Measurements are given as (min.–) x–SD – x+SD (–max.), where x is the average and SD the standard deviation. Photographs were taken with a Levenhuk C510 NG camera on an Optica Italica stereomicroscope and MICROMED-2 microscope. All examined specimens are deposited in the lichenological herbarium of the Kherson State University, Ivano-Frankivsk, Ukraine (KHER) and in the personal herbarium of the first author (herb. VD).

Pure cultures were obtained from a multiconidial culture (Bomar & Knöpfel 1992). Malt extract agar (MEA) and potato dextrose agar (PDA) were used for isolation of the fungal colonies (Crous & al. 2009). Fungi isolates were deposited in culture collection of Kherson State University, but they are currently unavailable for research.

DNA extraction, amplification and sequencing

Fungal genomic DNA was extracted from fresh mycelium and pycnidia grown on PDA at 25°C for 2 months using a modified CTAB-method (Doyle & Doyle 1990, Tarieiev & al. 2011). The internal transcribed spacer (ITS) region was PCR amplified and sequenced using universal primers ITS1–ITS4 and ITS4–ITS5 according to White & al. (1990). The PCR cycle protocols followed Ekman (2001). PCR products were visualized on a 1% agarose gel using ethidium bromide. Purification and sequencing of the PCR amplicons with ITS1 and ITS4 primers was conducted at Macrogen Inc. (http://www.Macrogen.com, The Netherlands).

Table 1. Strains and sequences used in the phylogenetic analyses.
The new sequence is indicated in **bold.** Type vouchers are annotated as [T].

Taxon	Voucher	Host	ITS
Ascochyta pisi	CBS 108.26	—	MH854853
	Netherlands, CBS 122785 [T]	—	GU237763
	Iran, MoKhol3-2	*Lathyrus sativus*	MT351037
Calophoma clematidina	Netherlands, CBS 108.79	—	MH861182
	Netherlands, CBS 520.66	—	MH858873
	Netherlands, CBS 108.79 [T]	—	FJ426989
	Netherlands, CBS 201.49	—	FJ426991
	Netherlands, CBS 195.64	*Clematis* × *jackmanii*	FJ426990
	Netherlands, CBS 520.66	*Selaginella* sp.	FJ426992
Chaetopyrena penicillata	**Ukraine, KHER 10840**	***Xanthoria parietina***	**MW478633**
	Iran, Khodaei P4I1	*Prunus divaricata*	MK100126
	Iran, Arzanlou S5	*Elaeagnus angustifolia*	MK100127
	Iran, Khodaei T312I1	*Salix alba*	MK100128
	Iran, Khodaei T22I1	Plant litter	MK100129
	China, HGAU-091001	—	KC492443
	CCTU 260	*Elaeagnus angustifolia*	JQ663990
Didymella exigua	France, CBS 183.55 [T]	*Rumex arifolius*	EF192139
D. pisi (= *Ascochyta pisi*)	—	—	GU722316
Neoascochyta exitialis	Switzerland, CBS 389.86	—	MH861971
	Sweden, CBS 113693	*Allium* sp.	KT389513
	CBS 118.40	—	KT389514
	Netherlands, CBS 389.86	*Triticum aestivum*	KT389515
	Germany, CBS 811.84	*Secale cereale*	KT389516
	Germany, CBS 812.84	*Hordeum vulgare*	KT389517
Phoma clematidina (≡ *Calophoma clematidina*)	Netherlands, PD 95.895	*Clematis* sp.	FJ515599
P. herbarum	C61	—	JQ936277
	C108.1	—	JQ936274
	C28.4	—	JQ936275
Pyrenochaeta nobilis	Italy, CBS 407.76 [T]	—	EU930011
	CBS 292.74	—	MH860856
Pyrenochaetopsis leptospora	CBS 101635 [T]	—	JF740262
P. microspora	Montenegro, CBS 102876	—	MH862809
	Brazil, PB147	*Cocos nucifera*	MK508814

Sequence alignment and phylogenetic analysis

The quality of the newly produced sequence was manually checked using sequence chromatogram in Chromas software (Technelysium Pty Ltd; http://www.technelysium.com.http://au/chromas.html) and edited in BioEdit 7.2.5 (Hall 1999). We used a BLASTN search (Altschul & al. 1990) in the GenBank database for primary taxonomic interpretation of the sequence. The final analyses included the newly generated sequence and available NCBI accession number sequences with complete ITS1 region of *Chaetopyrena* and selected genera of *Didymellaceae* such as *Ascochyta*, *Calophoma*, *Didymella*, *Neoascochyta*, *Phoma* (Table 1). *Pyrenochaetopsis leptospora* (Sacc. & Briard) Gruyter & al. was used as outgroup. The ITS region was aligned using MAFFT 7 (Katoh & Standley 2013) with L-INS-i method (Katoh & al. 2005). The final ITS alignment contained 456 positions and 36 sequences. To determine the evolutionary models that fit best for the data set, the program jModeltest 2.1.7 (Darriba & al. 2012) was used. The best nucleotide substitution model GTR+G+I (Tavaré 1986) was selected using the Maximum Likelihood value (–lnL) criterion (Posada & Crandall 1998). Phylogenetic reconstruction of the resulting alignment was carried out using the Metropolis-coupled Markov chain Monte Carlo (MCMC) approach in MrBayes v.3.2 (Ronquist & al. 2012). Two parallel simultaneous runs, each using four independent chains and starting from a random tree, were performed over 10 000 000 generations; tree sampling was carried out every 1000th generation. The first 25% of saved data was discarded as burn-in and the 50% majority-rule consensus tree and posterior probabilities (PP) were calculated from the remainder. A maximum likelihood (ML) approach was applied to the same data using IQTree Web Server (Trifinopoulos & al. 2016) with the GTR evolutionary model selected. Non-parametric bootstrap analysis was performed with 1000 ultrafast bootstrap replicates. The maximum likelihood consensus tree is not shown, but bootstrap values (BS) are indicated at branches in the Bayesian tree. Well supported clades were considered with PP >0.95 and BS >70 The alignment and tree used in this study are publicly available in TreeBase (ID: 27741). The final tree was visualized and modified in FigTree v.1.4.4 and Inkscape v.1.0.2 software (https://inkscape.org/, Rambaut & Drummond 2018).

Phylogenetic results

Phylogeny. Maximum likelihood (ML) and Bayesian trees had no topological conflicts in the clades. Newly generated and other sequences of *Chaetopyrena penicillata* formed a well-supported monophyletic clade (PP = 1, BS = 100) within *Didymellaceae* and were sister to *Calophoma* Qian Chen & L. Cai (type species *Calophoma clematidina* (Thüm.) Qian Chen & L. Cai) and *Ascochyta* Lib. (type species *Ascochyta pisi* Lib.) (Fig. 1).

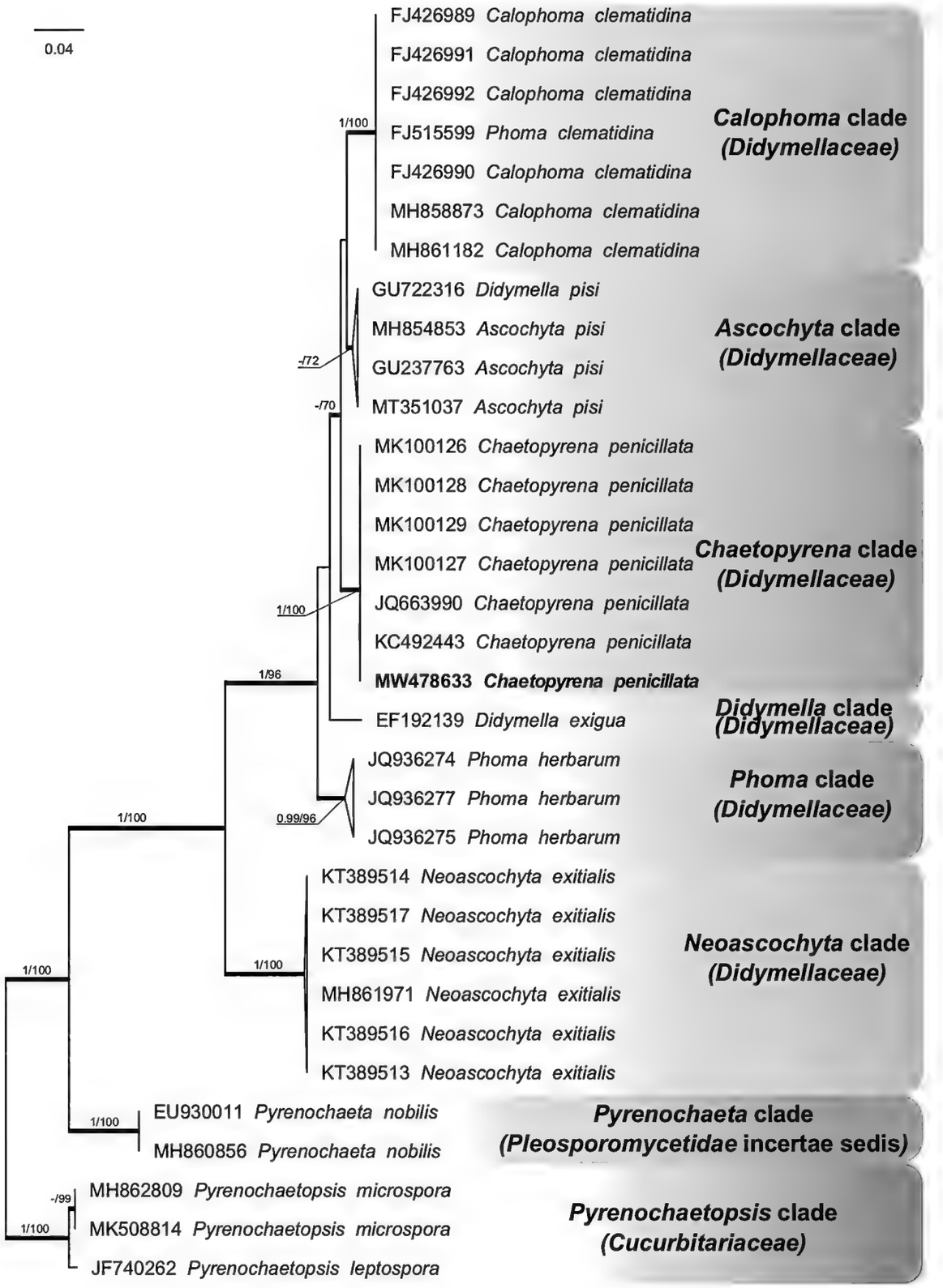

Fig. 1. Internal transcribed spacer (ITS)-based 50% majority-rule unrooted consensus tree based on a Bayesian approach for *Chaetopyrena penicillata*. Bold branches represent either bootstrap values ≥70 and/or Bayesian posterior probabilities ≥0.97. Newly generated sequence is indicated in bold.

Taxonomy

Chaetopyrena penicillata (Fuckel) Höhn., Hedwigia 60: 132 (1918) Fig. 2

Description in vivo (from specimen on *Xanthoria parietina*)— Conidiomata pycnidia, globose to ellipsoid, fully immersed at first, emerged up to superficial when mature, dark brown to brown-black, (90–)105–140 (–150) × (80–)85–115(–125) µm [*n* = 20]; pycnidia covered around the ostiole with erect, brown, 4–5-septate setae, (65–)80–130(–150) × (4.0–) 5.0–6.6(–7.2) µm [*n* = 20]; pycnidial wall of 3–4 layers (textura angularis), (15–) 18–32(–35) µm [*n* = 20] thick, cells (8.4–)9.6–13.8(–15.4) × (6.0–)7.4–9.8 (10.2) µm [*n* = 25], with an amorphous brown pigment in cellular walls; conidiophores reduced to conidiogenous cells or with a single supporting cell, ampulliform, hyaline, smooth, with periclinal thickening, (5.2–)6.4–8.2 (–9.0) × (4.2–)5.4–7.6(–8.4) µm [*n* = 20]; conidia solitary, 1-celled, hyaline, smooth, cylindrical with rounded ends, often slightly constricted in the middle (dumbbell-shaped), (11.6–)13.0–15.6(–16.4) × (2.2–)3.2–3.8(–4.4) µm [*n* = 60].

Description in vitro (PDA) – Vegetative hyphae (3.2–)4.2–6.6(–7.2) µm wide [*n* = 25] with oil drops, conidiomata pycnidia, subglobose to pyriform, initially hyaline (3–5 days), then dark brown to brown-black (14 days), erumpent with one or few (2–3) necks, (150–)230–300(–360) µm wide and (300–)340–440(–520) µm high [*n* = 30]; neck (90–)120–240(–300) [*n* = 20] µm long, with a central ostiole, ≤30 µm diam., setose; setae 2–3-septate, medium brown, numerous, erect, smooth, tapering towards hyaline to pale brown obtuse ends, (75–)100–170(–225) × (3.0–)5.2–8.4(–9.6) µm [*n* = 40]; pycnidial wall of 3–5 layers (textura angularis), (30–)40–50(–60) µm [*n* = 30] thick, internal layer thin, hyaline to pale brown, outer layer wider, medium brown to dark brown; cells (5.2–)8.2–14.4(–18.4) × (4.0–)6.2–10.8(–14.2) µm [*n* = 40], with an amorphous brown pigment in cellular walls; conidiophores reduced to conidiogenous cells or with a single supporting cell, ampulliform, hyaline, smooth, with periclinal thickening, (6.2–)7.2–9.8(–10.4) × (5.2–) 7.6–9.8(–10.0) µm [*n* = 20]. Conidia solitary, 1-celled, hyaline, smooth, cylindrical with obtuse ends, rarely pyriform to slightly constricted in the middle, (12.0–)13.0–14.6(–15.4) × (2.6–)3.2–4.6(–5.6) µm [*n* = 60].

Culture characteristics – On MEA, colonies flat, ≤2.5 cm diam. after 7 days, spreading with sparse hyaline aerial mycelium, hyaline to pale brown internal mycelium, even, smooth margins, surface dirty white to pale brown,

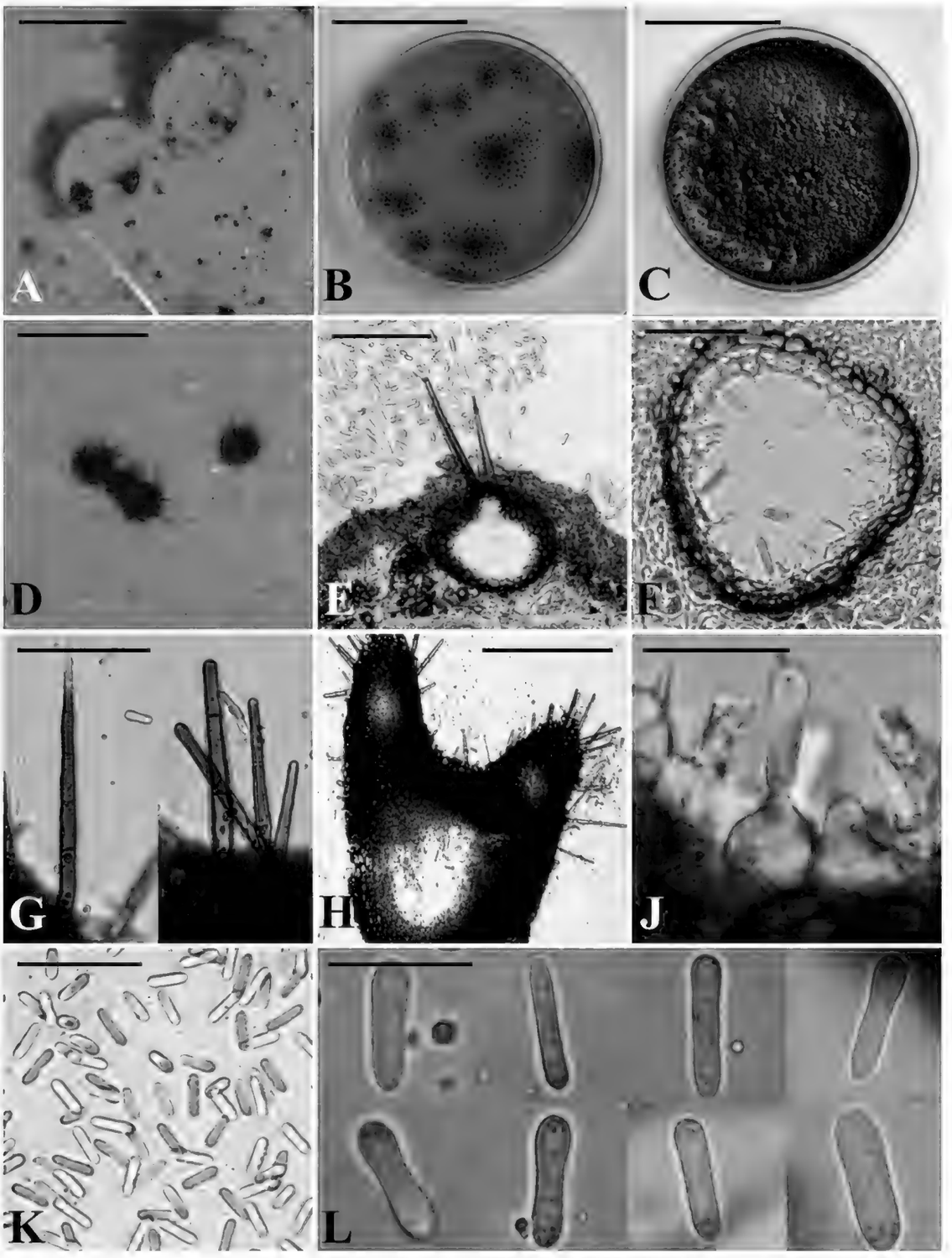

Fig. 2. *Chaetopyrena penicillata* (KHER 10840): A. pycnidia on apothecia of *Xanthoria parietina*; B. one month old culture (MEA); C. one month old culture (PDA); D. pycnidia (MEA); E. section through pycnidium (in water); F. pycnidial wall, conidiogenous cells, and conidia (in water); G. setae (in water); H. apical taper of pycnidium (in water); J. ampulliform conidiogenous cells and conidium (in water); K, L. conidia (in water). Scale bars: A, D = 1 mm; B, C = 5 cm; E, H = 100 μm; F, G, K = 50 μm; J = 25 μm; L = 15 μm.

similar in reverse. On PDA, colonies flat, ≤6 cm diam. after 7 days, spreading with hyaline to pale brown sparse aerial mycelium, medium brown to dark brown internal mycelium, even, smooth margins, surface olivaceous-grey to lead-black, olivaceous-black in reverse.

Specimens examined – **UKRAINE. Kherson region. Skadovskyi district**, village Kardashynka, private summer house, 46.5548°N 32.6463°E, alt. 1 m, on *Xanthoria parietina*, on *Salix alba*, 28.XII.2015, A. Khodosovtsev (KHER 10840; culture KHER_56 NCBI accession number MW478633); **Mykolaiv region, Pervomaiskyi district,** near Kuripchyne village, National Nature Park Buzkyi Gard, 47.9953°N 31.0017°E, alt. 48 m, on *Peltigera rufescens*, on soil, 21.IX.2019, V. Darmostuk (herb. VD 281); **Voznesenskyi district,** near Vysoka Hora village, Dubova balka, 47.8908°N 31.6131°E, alt. 37 m, on *Physcia stellaris* and *X. parietina*, on *Fraxinus* twig, 21.X.2020, V. Darmostuk (herb. VD 906).

Ecology—*Chaetopyrena penicillata* was originally described from stems of *Medicago sativa* (Fuckel 1867) and subsequently reported as a saprotroph on dry leaves of *Medicago* spp. and on fruits of *Elaeagnus angustifolia* showing dry rot symptoms (Arzanlou & Khodaei 2012), endophytic in stems of *Ephedra intermedia* (Wang & al. 2016), and from leaves of *Fraxinus chinensis* (Vettraino & al. 2017). Moreover, it is known as a saprophyte on soil, dead twigs, fruit, and stubble (Wang & al. 2016). Here it is reported for the first time growing on the lichens *Peltigera rufescens*, *Physcia stellaris,* and *Xanthoria parietina*, forming pycnidia on weakened thalli and apothecia in wet seasons. The infection of lichens by *Chaetopyrena penicillata* does not induce gall formation, but sometimes (depending on the host species) causes a discoloration of the host thallus; on *Xanthoria parietina* it does not induce discoloration, but we observed totally discolored thalli on *Physcia stellaris*, and a few necrotic parts on *Peltigera rufescens.*

Distribution—Specimens on *Physcia stellaris* and *Peltigera rufescens* have the same morphological features. Our data fit the measurements given by other authors (Fuckel 1867, Arzanlou & Khodaei 2012, Wang & al. 2016). The fungus is known from Europe (Czech Republic, Germany, Romania, Russia), Asia (China, Iran, Turkey), and Africa (South Africa) (Fuckel 1867, Arzanlou & Khodaei 2012, Wang & al. 2016). It is here reported from Ukraine for the first time.

Comments—Visually, *Chaetopyrena penicillata* is similar to *Pyrenochaeta xanthoriae,* which can be distinguished by acro-pleurogenous conidiogenous cells and shorter conidia (Diederich 1990). Another lichenicolous coelomycete with setose pycnidia "*Pyrenochaeta*" *collematis* Vouaux has cylindrical

conidiogenous cells and smaller conidia and grows on thalli of *Enchylium tenax* (Hawksworth 1981, Clauzade & al. 1989). This species is dubious due to the lost type and lack of modern records and description. The facultatively lichenicolous *Pyrenochaetopsis microspora* (Gruyter & Boerema) Gruyter & al. (*Cucurbitariaceae*) differs by much smaller conidia (3.5–4.5 × 1.5–2 µm vs. 12–15.5 × 2.6–5.7 µm in *C. penicillata;* de Gruyter & Boerema 2002). The asexual stage of *Coniothyrium sidae* Quaedvl. & al. (*Coniothyriaceae*) differs in slightly smaller (9–13 × 2.5–3 µm) conidia and smaller (4–7 × 4–6 µm) conidiogenous cells and grows on the angiosperm *Sida* (Quaedvlieg & al. 2013). The setose coelomycetous *Paraphoma* Morgan-Jones & J.F. White and *Setophoma* Gruyter & al. belong to different clades within *Phaeosphaeriaceae* (de Gruyter & al. 2010) and have slight morphological differences. *Dinemasporium strigosum* (Pers.) Sacc., a common coelomycete, growing mostly on dead grasses but also reported from *Peltigera* thalli, differs in producing conidia with a single filiform appendage at each end (Sutton 1980, Nag Raj 1993, Sérusiaux & al. 2003). Lichenicolous coelomycetes with setose pycnidia are also known in *Karsteniomyces* D. Hawksw. and *Keratosphaera* H.B.P. Upadhyay (Upadhyay 1964, Boqueras & Diederich 1993, Matzer 1996).

Key to the lichenicolous coelomycetes with setose pycnidia

1. Setae light brown to brown 2

1. Setae hyaline, conidiophores cylindrical, 30-40 µm long, conidiogenous cells monoblastic, indistinguishable from conidiophores, conidia hyaline, elongate, 1-septate, on *Parmelina quercina* ..... *Karsteniomyces llimonae*

2. Conidia with filiform apical appendages 3

2. Conidia without filiform apical appendages 7

3. Conidia ≤20 µm long 4

3. Conidia 25–30 µm long, with a single filiform appendage at each end, on *Peltigera* and (rarely) other (foliose) lichens ..... *Dinemasporium strigosum*

4. Conidia 0-1-septate 5

4. Conidia 2-4-septate, on *Mazosia phyllosema* ..... *Keratosphaera batistae*

5. Setae unforked at the distal end 6

5. Setae one or twice shortly forked at the distal end, on *Porina epiphylla* ..... *Keratosphaera furcatiseta*

6. Apical part of setae distinctly pointed and paler, 35 × 8 µm, on *Porina epiphylla* and *Pyrenula nitida* ..... *Keratosphaera porinae*

6. Apical part of setae not pointed and not paler, 16 × 4 µm, on *Dimerella* spp. ..... *Keratosphaera dimerellae*

7. Conidiogenous cells cylindrical, 1.5–2.5 µm diam. 8
7. Conidiogenous cells ampulliform, 5–10 µm diam. 9

8. Conidiogenous cells arising from elongate septate conidiophores, conidia 3–3.5(–4) × 1.4– 1.8(–2) µm, on *Xanthoria* .... *Pyrenochaeta xanthoriae*
8. Conidiophores reduced to the conidiogenous cell, conidia 5–6 × 2 µm, on *Enchylium* ..... *"Pyrenochaeta" collematis*

9. Conidia 3.5–4.5 × 1.5–2 µm, on *Buellia* ..... *Pyrenochaetopsis microspora*
9. Conidia 12–15.5 × 2.6–5.7 µm, on *Peltigera*, *Physcia,* and *Xanthoria* ..... *Chaetopyrena penicillata*

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New records and hosts of lichenicolous fungi from India

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Abstract—Eight lichenicolous fungi are reported as new records from India: *Cladophialophora* aff. *megalosporae*, *Nesolechia falcispora*, *Phacopsis oxyspora* var. *defecta*, *Punctelia oxyspora*, *Sclerococcum phaeophysciae*, *Scutula epiblastematica*, *Spirographa lichenicola*, and *Zwackhiomyces kantvilasii*. Also reported are new hosts for *Cladophialophora* aff. *megalosporae*, *Nesolechia falcispora*, *Sclerococcum phaeophysciae*, *Scutula epiblastematica*, and *Zwackhiomyces kantvilasii*.

Key words—biodiversity, *Lecanorales*, parmelioid lichens, taxonomy

Introduction

Lichenicolous fungi represent a highly specialized and successful group of organisms that live exclusively on lichens, most commonly as lichen parasites, but also as broad-spectrum pathogens, saprotrophs, or commensals (Diederich & al. 2018). A total of 2319 lichenicolous fungal species (Diederich & al. 2018) has been reported from different parts of the world, and many more species are being added to this list. The study of lichenicolous fungi in India has been initiated in the last decade, and at present there are 185 total taxa reported from the country (Joshi 2018, 2020, 2021; Singh & Singh 2019; Joshi & al. 2020a,b), far fewer than what has been

reported from many other countries. The herbarium LWG of CSIR-National Botanical Research Institute, Lucknow harbors a rich collection of lichen comprising almost 150,000 specimens. Several interesting taxa have been found during the examination of lichenicolous fungi from these herbarium materials.

Here we report eight lichenicolous taxa new to India and growing mainly on parmelioid lichens. The continual discovery of lichenicolous fungi in recent years indicates that India has a high diversity of these organisms yet to be explored. Several ongoing studies on lichenicolous fungi promise to add to Indian biodiversity.

Materials & methods

The specimens examined are housed in the Herbarium, CSIR-National Botanical Research Institute, Lucknow, India (LWG), which also includes herbarium of Lucknow University (LWG-LWU). They were examined morphologically using a Leica S8APO stereo zoom microscope and anatomically with a Leica DM2500 compound microscope. Hand-cut sections mounted in water were photographed with a Leica EC3 camera and analysed using LASEZ software. Amyloid reactions were tested in Lugol's iodine solution with or without KOH pretreatment. All measurements were taken from water mounts; the length, breadth, and length/breadth ratio is given as (min–){x–SD}–{x+SD}(–max), where 'min' and 'max' are the extreme values, x is the arithmetic mean, SD is standard deviation, and 'n' is the total number of measurements.

Taxonomy

Cladophialophora* aff. *megalosporae Diederich,
Fung. Divers. 58: 70, 2013. FIG. 1A,B

CONIDIOMATA forming brown to black-colored colonies on lichen thallus and apothecial margins, 0.15–3 mm wide, sessile to sub sessile, with immersed mycelium, brown to black; CONIDIOPHORES pale brown to brown; CONIDIA numerous, aseptate, subspherical, rarely adhering in short, branched, acropetal chains, pale brown to reddish brown, (2.5–)2.7–3.4 (–3.5) × (2.0–)2.2–2.7(–3.0) µm, l/b ratio (1.0–)1.1– 1.4(–1.6), (n = 20).

SPECIMENS EXAMINED: **INDIA, SIKKIM, North Sikkim**, Kalep before Thangu, elev. 3900 m, on *Hypotrachyna scytophylla* growing on bark, 12 August 2004, D.K. Upreti, S. Chatterjee & P.K. Divakar 04-003846 (LWG 14694); **UTTARAKHAND, Pithoragarh district**, Narayan Swami Asharam, elev. 2748 m, on *Myelochroa macrogalbinica* growing on bark, 2 November 2009, D.K. Upreti 09-013442 (LWG 13455).

COMMENTS—*Cladophialophora* aff. *megalosporae* has been reported from U.S.A., Papua New Guinea (Diederich & al. 2013), and Vietnam

(Zhurbenko & al. 2020). In India, the species is being reported from Sikkim and Uttarakhand. The closely related *C. hawksworthii* (Etayo & Diederich) Diederich differs from *C. megalosporae* by having larger (2.5–4 µm) conidia. The conidia of *C. hawksworthii* are greyish brown while *C. megalosporae* are brown to reddish-brown. Previously, *C. megalosporae* has been reported occurring only on crustose *Megalospora* spp., but in India it was found growing on the foliose lichens *Hypotrachyna scytophylla* (Kurok.) Hale and *Myelochroa macrogalbinica* Divakar & al. Additional collections may suggest Indian specimens as a new species due to the host variation. At present, we are treating it here as *Cladophialophora* aff. *megalosporae*.

Nesolechia falcispora (Triebel & Rambold) Diederich,
Bryologist 121: 394, 2018. FIG. 1C,D

APOTHECIA brown to black on lichen thallus, numerous, round, 0.1–0.35 mm, dispersed to crowded, sometimes forming gall like structures, immersed to sessile, margin indistinct; EXCIPULUM pale brown to brown, 20–40 µm thick; EPIHYMENIUM light brown to brown, 12–17 µm high; HYMENIUM hyaline to slightly brownish, 55–70 µm high, I–; PARAPHYSES septate, sometimes branched, with brown swollen tips; HYPOTHECIUM pale brown, 60–80 µm high, I+ violet; ASCI 8-spored, clavate, 50–55 × 15–18 µm, tholus I+ blue; ASCOSPORES hyaline, aseptate, falciform to lemon shaped, (10.1–)11.8–15.0(–16.3) × (3.8–)4.8–6.2(–7.2) µm, l/b ratio (1.6–)2.1–2.9 (–3.3), (n = 32).

SPECIMENS EXAMINED: **INDIA, HIMACHAL PRADESH, Shimla district**, Rohru, Jubbal, along Sandali naala, elev. 1650 m, on *Myelochroa aurulenta* growing on rock, 20 May 2002, S. Nayaka & R. Srivastava 02-87166 (LWG 17508); **SIKKIM, North Sikkim**, above Lachung towards Yumthang, elev. 3000 m, on *Hypotrachyna incognita* growing on rocks, 16 August 2004, D.K. Upreti, S. Chatterjee & P.K. Divakar 04-004243 (LWG 14761); **UTTARAKHAND, Chamoli district**, way of Nanda Devi Biosphere Reserve, Kanukdhara, elev. 3500 m, on *Flavopunctelia flaventior* growing on *Betula utilis*, 07 June 2008, S. Rawat 08-011232 (LWG 13207); Joshimath, elev. 1700 m, on *Punctelia subrudecta* growing on rock, 18 January 2008, S. Rawat 08-008800 (LWG 21404); **Champawat district**, Lohaghat, on *Myelochroa xantholepis* growing on bark, 29 October 2009, D.K. Upreti & al. 09-012659 (LWG 13417); **Uttarkashi district**, Govind Wildlife Sanctuary, Sankoni behind GMVN guest house, elev. 1975 m, 31.0791°N78.1844° E, on *P. subrudecta* growing on bark of apple tree, 07 November 2012, R. Bajpai 12-018922 (LWG 28563).

COMMENTS—*Nesolechia falcispora* was previously reported from South Africa (Triebel & al. 1995). In India, the species is found in the states of Himachal Pradesh, Sikkim, and Uttarakhand. The closely related species,

Punctelia oxyspora, differs from *N. falcispora* by having much larger (16–21 × 5–7 µm) falciform to lemon-shaped ascospores. The species was previously reported to occur only on species of *Usnea*, but in India many parmelioid lichens were found as its host. In India hosts include *Flavopunctelia flaventior* (Stirt.) Hale, *Hypotrachyna incognita* (Kurok.) Hale, *Myelochroa aurulenta* (Tuck.) Elix & Hale, *M. xantholepis* (Mont. & Bosch) Elix & Hale, and *Punctelia subrudecta* (Nyl.) Krog.

Phacopsis oxyspora var. ***defecta*** Triebel & Rambold,
Bryologist 98: 79, 1995. FIG. 1E,F

APOTHECIA semi immersed to immersed in host lichen thalli, crowded, 0.2–0.4 mm in diam., disc brown to dark brown, margin indistinct; EXCIPULUM 25–35 µm thick, pale brown; EPIHYMENIUM pale brown, 15–20 µm high; HYMENIUM hyaline, 40–60 µm high, I–; PARAPHYSES septate, anastomosed with dark brown swollen tips; HYPOTHECIUM colorless to pale brown, 40–80 µm high, I–; ASCI 8-spored, clavate, 43–52 × 14–17 µm, tholus I+ blue; ASCOSPORES hyaline, aseptate, mostly ellipsoid, (14.1–)14.5–16.5 (–17.6) × (5.1–)5.4–6.2(–6.6) µm, l/b ratio (2.1–)2.4–3.0(–3.2), (n = 15).

SPECIMENS EXAMINED: **INDIA, HIMACHAL PRADESH, Baes river valley**, Manali, elev. 1800 m, on *Punctelia rudecta* growing on *Cedrus deodara*, 15 June 1975, D.D. Awasthi & K. Dange 75-003 (LWG-LWU 15782); **Chamba district**, in and around Khajiar, elev. 2000 m, on *P. rudecta* growing on *Cedrus deodara*, 15 May 2001, D.K. Upreti & S. Nayaka 01-75438 (LWG 21441); **UTTARAKHAND, Chamoli district**, way of Nanda Devi Biosphere Reserve, Lata, elev. 2900 m, on *P. rudecta* growing on rock, 05 June 2008, S. Rawat 08-011078 (LWG 21561).

COMMENTS—*Phacopsis oxyspora* var. *defecta* is distributed in Asia, Australia, Europe, North America, and South America (Triebel & al. 1995). From India, *P. oxyspora* var. *defecta* is being reported from Himachal Pradesh and Uttarakhand. The closely related *Punctelia oxyspora* differs in having I+ violet reaction of hypothecium, while most other characters overlap. Our Indian specimens of *Phacopsis oxyspora* var. *defecta* seem more similar to *Punctelia oxyspora*, but we need to study the type material of the variety before considering our material as a new taxon. *Phacopsis oxyspora* var. *defecta* is known to occur on *Hypotrachyna incognita, H. sinuosa* (Sm.) Hale, *Notoparmelia tenuirima* (Hook. f. & Taylor) A. Crespo & al., *Parmelia fraudans* (Nyl.) Nyl., *P. saxatilis* (L.) Ach., *P. sulcata* Taylor, *Punctelia punctilla* (Hale) Krog, *P. rudecta* (Ach.) Krog, *P. semansiana* (W.L. Culb. & C.F. Culb.) Krog, and *P. subrudecta*.

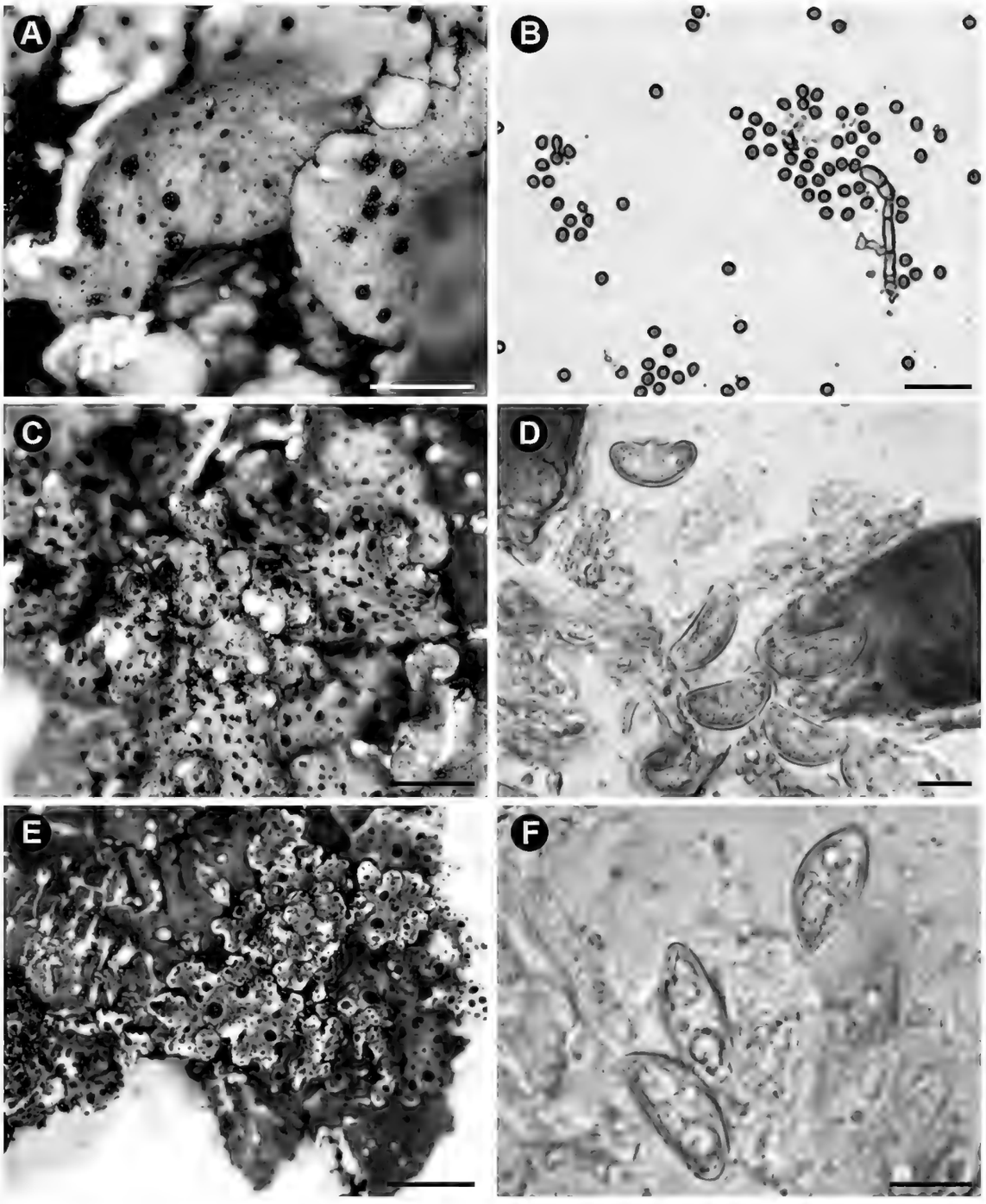

Fig. 1. ***Cladophialophora* aff. *megalosporae*** (LWG 14694): A. sporodochia developing on the thallus of *Hypotrachyna scytophylla*; B. conidiophore, conidiogenous cells, and conidia; ***Nesolechia falcispora*** (LWG 21404): C. apothecia immersed on the thallus of *Punctelia subrudecta*; D. falciform ascospores; ***Phacopsis oxyspora* var. *defecta*** (LWG 15782): E. apothecia spread on the thallus of *Punctelia rudecta*; F. ellipsoid ascospores. Scale bars: A, C, E = 0.2 mm; B, D, F = 10 μm.

Punctelia oxyspora (Tul.) Divakar, A. Crespo & Lumbsch,
Fung. Divers. 84: 114, 2017. FIG. 2A,B

APOTHECIA immersed in host lichen thalli, round, crowded, dark brown in color, 0.2–0.5 mm in diam., margin indistinct; EXCIPULUM hyaline, 12–38 µm thick; EPIHYMENIUM brown, 12–15 µm high; HYMENIUM hyaline, 50–70 µm high, I–; PARAPHYSES septate, anastomosed, with brown to dark brown swollen tips; HYPOTHECIUM colorless, 60–100 µm high, I+ violet; ASCI clavate, 8-spored, 46–50 µm, I+ blue; ASCOSPORES ellipsoid, hyaline, (14.1–)14.3–16.3(–17.3) × (5.1–)5.5–6.5(–7.2) µm, l/b ratio (2.0–)2.3–2.9 (–3.0), (n = 15).

SPECIMEN EXAMINED: **INDIA, HIMACHAL PRADESH, Kinnaur district**, Rackshum-Chitkul, elev. 3500 m, on *Melanelixia glabratula* growing on *Acer* tree trunk, 5 November 2003, Upreti, Srivastava & Prakash 03-002776 (LWG 17219).

COMMENTS—*Punctelia oxyspora* has been reported from Asia, Europe, and North America (Triebel & al. 1995). From India, the species is being reported from Himachal Pradesh state. The closely related *Phacopsis oxyspora* var. *defecta* differs in having I– hypothecium. *Punctelia oxyspora* occurs on *Hypotrachyna nepalensis* (Taylor) Divakar & al., *Melanohalea olivacea* (L.) O. Blanco & al., *Melanelixia glabratula* (Lamy) Sandler & Arup, *Parmelia fraudans, P. saxatilis, P. sulcata, Platismatia glauca* (L.) W.L. Culb. & C.F. Culb., and *Punctelia rudecta*.

Sclerococcum phaeophysciae Diederich & van den Boom,
Bull. Soc. Naturalistes Luxemb. 119: 72, 2017. FIG. 2C,D

SPORODOCHIA dark brown to black colored, superficial on lichen thallus, round to elongate, 0.4–0.7 mm; CONIDIOPHORES aggregated, not branched, hyaline to pale brown; CONIDIOGENOUS CELLS terminal, hyaline to pale brown; CONIDIA pale brown, 1-septate, subspherical to ellipsoid, I–, (12.1–)13.2–15.3(–16.9) × (3.6–)7.6–9.6(–10.8) µm, l/b ratio (1.3–)1.4–1.9 (–2.5) µm, (n = 50).

SPECIMEN EXAMINED: **INDIA, TAMIL NADU, Nilgiri Hills**, Emerald Beat, opposite Mukurti lake and Nilgiri Peak, elev. 2286 m., on *Hypotrachyna exsecta* growing on bark of *Rhododendron* tree, 25 December 1971, K.P. Singh (LWG-LWU 71.755).

COMMENTS—*Sclerococcum phaeophysciae* is known from Belgium, Germany, Luxembourg, and Netherlands (Diederich & van den Boom 2017). From India, the species is being reported from Tamil Nadu. The only other *Sclerococcum* species known to have 1-septate conidia is *S. montagnei* Hafellner, which is distinguished by much smaller (10–13 × 6–9 µm)

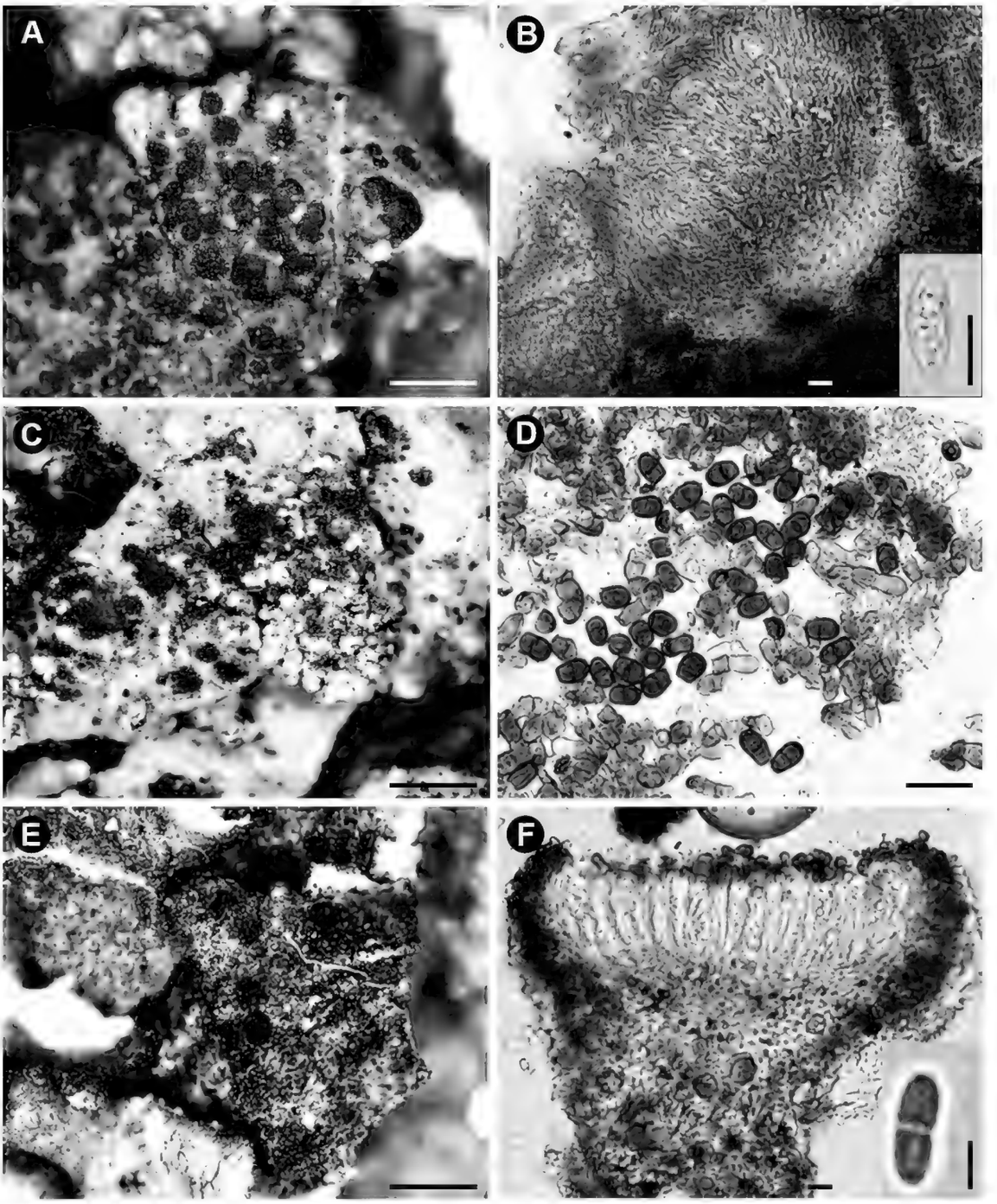

Fig. 2. ***Punctelia oxyspora*** (LWG 17219): A. apothecia; B. section of ascomata with I+ violet hypothecium (inset: an enlarged view of ascospore); ***Sclerococcum phaeophysciae*** (LWG 71.755): C. sporodochia developing on the thallus of *Hypotrachyna exsecta*; D. conidiophores, conidiogenous cells, and conidia; ***Scutula epiblastematica*** (LWG 25892): E. apothecia on thallus of *Xanthoparmelia stenophylla*; F. section of ascomata (inset: an enlarged view of ascospore). Scale bars: A, C, E = 0.2 mm; B, F = 10 µm; D = 30 µm.

conidia, which occasionally can be aseptate or submuriform. Previously, *S. phaeophysciae* was reported growing on *Phaeophyscia orbicularis* (Neck.) Moberg (Diederich & van den Boom 2017), but in India, it was found growing on *Hypotrachyna exsecta* (Taylor) Hale.

Scutula epiblastematica (Wallr.) Rehm,
Rabenh. Krypt. Fl. ed. 2, 1(3): 322, 1890. FIG. 2E,F

APOTHECIA numerous, aggregated, sessile, adnate, scattered, 0.1–0.3 mm diam., black, margin distinct, black; EXCIPULUM olivaceous to brown, 17–24 µm thick, not carbonaceous; EPIHYMENIUM brown, 6–10 µm high; HYMENIUM hyaline, 21–30 µm high, I+ blue; PARAPHYSES hyaline, unbranched, capitate, tips swollen, brown; HYPOTHECIUM hyaline, 15–20 µm high, I–; ASCI 8-spored, clavate, 20–25 × 3–6 µm; ASCOSPORES hyaline, 1-septate, ellipsoid, I–, (7.2–)7.7– 9.9(–11.8) × (2.2–)2.7–3.9(–5.0) µm, l/b ratio (2.0–)2.4–3.1 (–3.4) µm, (n = 28).

SPECIMENS EXAMINED: **INDIA, HIMACHAL PRADESH, Kinnaur district**, Recong Peo, in and around Kalpa, elev. 2950 m, on *Xanthoparmelia stenophylla* growing on rock, 3 November 2003, Upreti, Srivastava & Prakash 03-002657 (LWG 25892); **JAMMU & KASHMIR, Pahalgam**, on the left of the river; elev. 2134 m, on *Melanelixia glabra* growing on bark of tree trunk, 1 July 1977, K. Dange 77.409 (LWG-LWU 41226).

COMMENTS—*Scutula epiblastematica* has been reported from Africa, Asia, Europe, and North America (Holien 2005). In India, the species is being reported from Himachal Pradesh and Jammu & Kashmir. The closely related species *S. tuberculosa* (Th. Fr.) Rehm and *S. miliaris* (Wallr.) P. Karst. differ from *S. epiblastematica* by having longer and broader (10–14 × 4–6 µm) ascospores (Wedin & al. 2007). *S. epiblastematica* was earlier reported to grow on different *Peltigera* species, but in India it was found growing on *Melanelixia glabra* (Schaer.) O. Blanco & al. and *Xanthoparmelia stenophylla* (Ach.) Ahti & D. Hawksw.

Spirographa lichenicola (D. Hawksw. & B. Sutton) Flakus, Etayo & Miądl.,
Pl. Fung. Syst. 64: 328, 2019. FIG. 3A,B

CONIDIOMATA pycnidial, pale brown, immersed to erumpent, solitary, sometimes in group, making the nearby thallus area discolored and surrounded by a black circular necrotic margin, ostiole invisible; PYCNIDIAL WALL hyaline; CONIDIOPHORES hyaline, septate and sometimes branched, 25–35 µm high; CONIDIA hyaline, Y-shaped, aseptate, with two distinct arms, I–, main conidial axes (6.0–)6.3–7.3(–7.6) × (1.5–)1.6–1.8(–1.9) µm, l/b ratio (3.2–)3.5–4.3(–4.8), (n = 11).

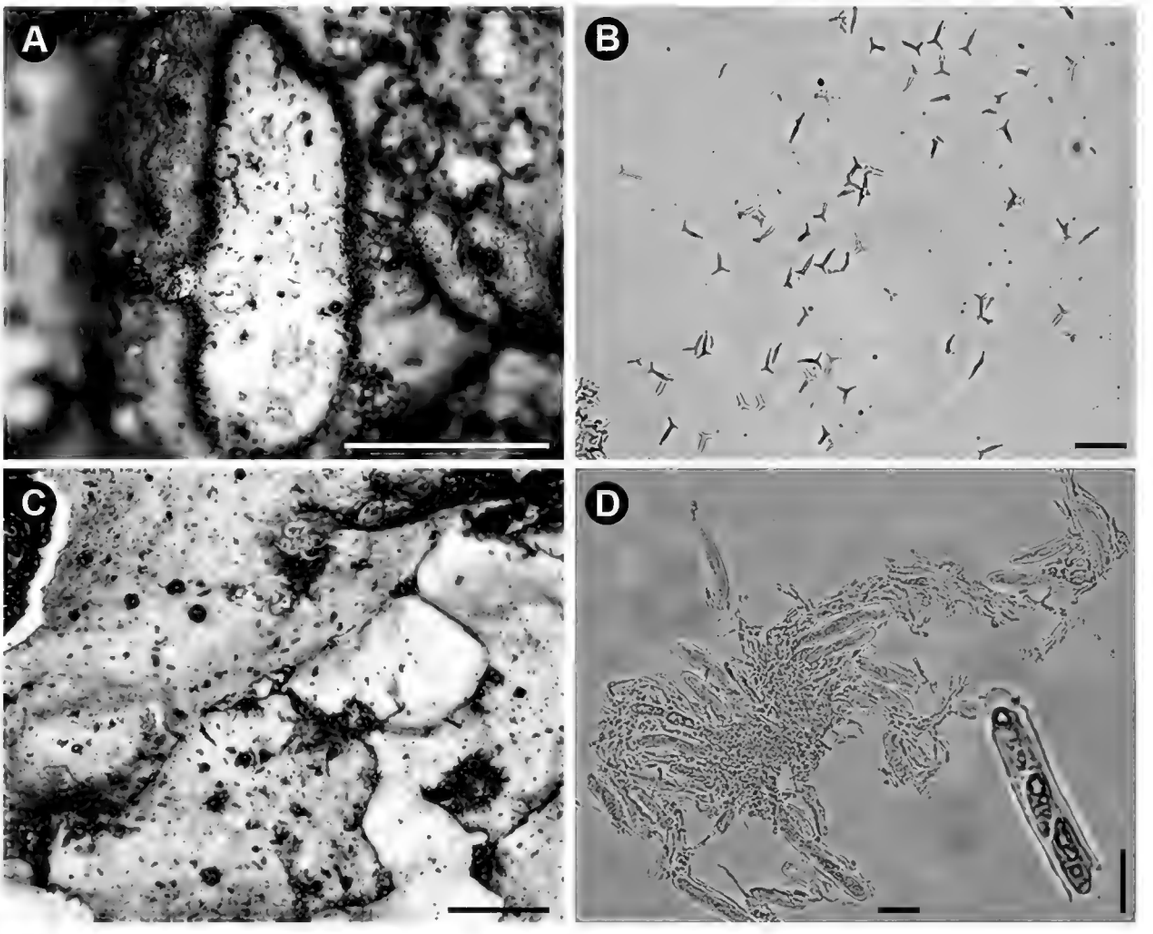

Fig. 3. ***Spirographa lichenicola*** (LWG 008849): A. infected area on thallus; B. Y-shaped conidia; ***Zwackhiomyces kantvilasii*** (LWG 19790): C. perithecia; D. section of perithecia (inset: an enlarged view of ascospore). Scale bars: A = 0.1 mm; B = 20 µm; C = 0.2 mm; D = 10 µm.

Specimens examined: **INDIA, Himachal Pradesh, Kullu district**, Great Himalayan National Park, Sairopa, elev. 1440 m, on *Canoparmelia texana* growing on fallen twigs, 10 November 2002, S. Nayaka & R. Srivastava 02-000543 (LWG 008849); **Uttarakhand, Chamoli district**, Gwaldam, elev. 1650 m, on *C. ecaperata* growing on bark of *Taxus*, 03 May 2015, S. Rawat 15-27383 (LWG 33010); **Uttarkashi district**, Govind Wildlife Sanctuary, Judatal to Kedarnath, elev. 3400 m, 30.0335°N 78.1795°E, on *C. texana* growing on bark, 06 October 2013, R. Bajpai 13-020160 (LWG 17325).

Comments—*Spirographa lichenicola* has been reported from British Isles (Hawksworth 1976), Africa, Australia, and North America (Hafellner & al. 2002), Bosnia and Herzegovina (Bilovitz & al. 2010), Bolivia (Flakus & Kukwa 2012), and Russia (Himelbrant & al. 2013). From India, the species is being reported from the states of Himachal Pradesh and Uttarakhand. *Spirographa lichenicola* differs from all other *Spirographa* species because of the absence of bulbous arms (Punithalingam 2003). The closely related

S. limaciformis (Piroz.) Flakus & al. differs from *S. lichenicola* with much larger (≥13–22 µm) conidia. *Spirographa lichenicola* is known to occur on *Canoparmelia ecaperata* (Müll. Arg.) Elix & Hale, *C. texana* (Tuck.) Elix & Hale, *Lecanora chlarotera* Nyl., *Parmelia sulcata, Melanohalea olivacea, Parmelia saxatilis,* and *Platismatia glauca.*

Zwackhiomyces kantvilasii S.Y. Kondr.,
Muelleria 9: 98, 1996. FIG. 3C,D

PERITHECIA black, globose, scattered, semi-immersed to superficial on lichen thallus; PERITHECIAL WALLS 21–34 µm thick, brown throughout; HAMATHECIUM hyaline, I–; PARAPHYSES branched; ASCI 4-spored, cylindrical, 50–80 × 8–10 µm; ASCOSPORES hyaline, 1-septate, ellipsoid, I–, 3–4 guttulate, (14.2–)14.8–16.6(–17.7) × (4.3–)4.5–5.5(–5.7) µm, l/b ratio (2.5–)2.8–3.6(–3.7), (n = 11).

SPECIMEN EXAMINED: **INDIA, UTTARAKHAND, Chamoli district**, between Gondar and Laink, elev. 1550 m, on *Myelochroa irrugans* growing on rock, 20 September 1975, A. Singh & M. Ranjan 107082 (LWG 19790).

COMMENTS—*Zwackhiomyces kantvilasii* was previously reported from Tasmania (Kondratyuk 1996), Europe (Berger & Zimmermann 2016), and Japan (Zhurbenko & al. 2015). From India, the species is being reported from Uttarakhand state. *Zwackhiomyces kantvilasii* closely resembles *Z. physciicola* Alstrup, which differs in having 4–6-spored asci. In addition, the spores of *Z. physciicola* are much longer and broader (18–22 × 5.5–6.5 µm). *Zwackhiomyces kantvilasii* was earlier reported as occurring only on the thallus of *Parmotrema* spp., but in India, it was found growing on *Myelochroa irrugans* (Nyl.) Elix & Hale.

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Regional annotated mycobiota new to the Mycotaxon website:

Abstract—The recently submitted 62-page "Checklist of rust fungi (*Pucciniales*) in Pakistan" by Afshan & Khalid will be available for downloading from the Mycotaxon mycobiota webpage following final editorial approval during April 2023. This will bring to 156 the number of free access fungae uploaded or linked to http://www.mycotaxon.com/mycobiota/index.html

INDIAN SUBCONTINENT

Pakistan

N.S. AFSHAN & A.N. KHALID. Checklist of rust fungi (*Pucciniales*) in Pakistan. ~62 p.

Abstract—This paper presents a checklist of rust fungi in Pakistan together with their host plants. The 355 rust taxa cited here represent 33 genera, including 196 *Puccinia* and 61 *Uromyces* species. A host-rust index is also provided.

Key words—*Basidiomycota,* biotrophic fungi, taxonomy

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Abstract—After final editorial review, the recently submitted "Airborne mycotoxigenic fungi in Türkiye and Poland" by Giray, Zimowska, and Asan will be available for downloading from the Mycotaxon mycobiota webpage. This will bring to 157 the number of free access fungae uploaded or linked to http://www.mycotaxon.com/mycobiota/index.html

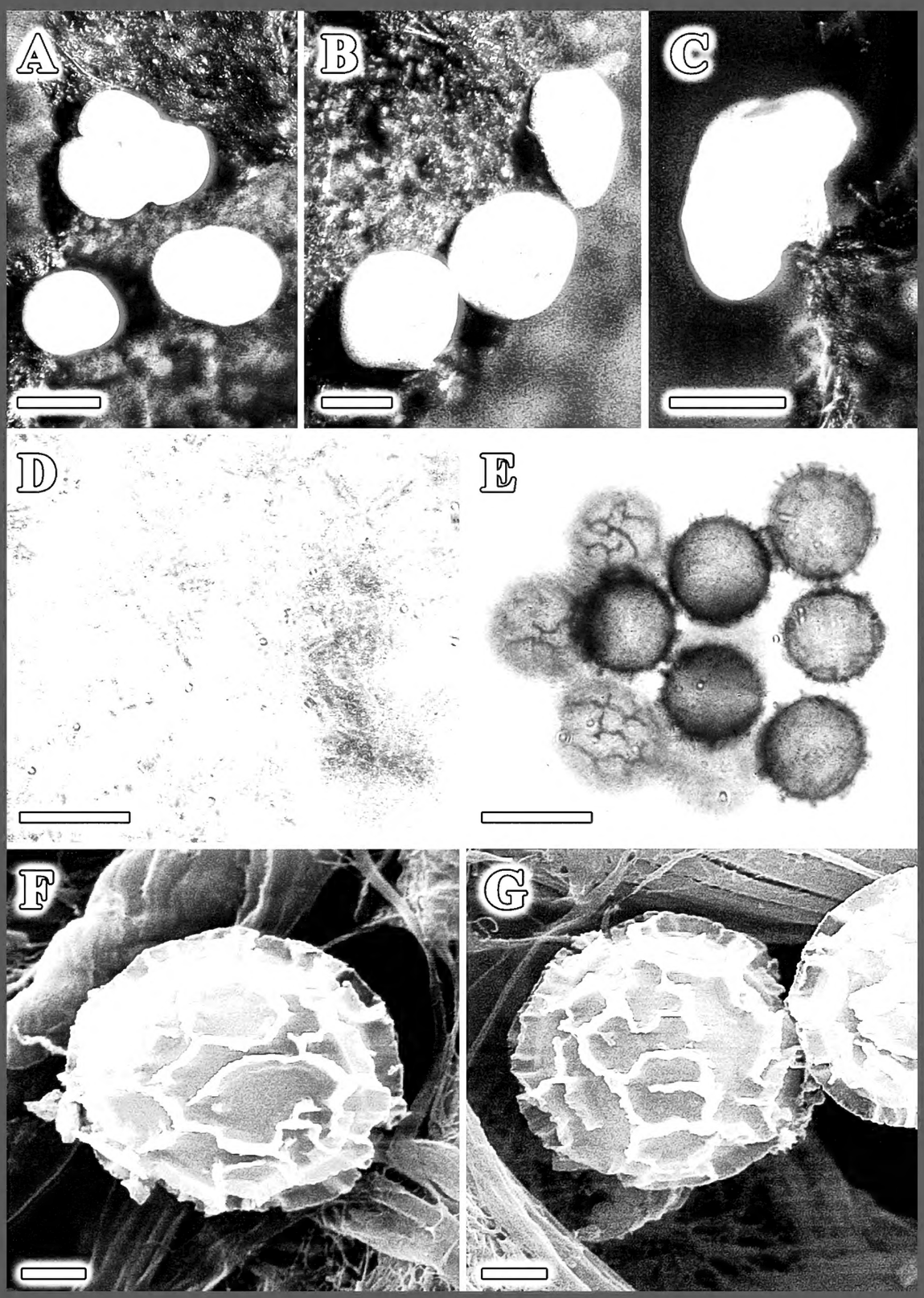
MID-EAST

Türkiye

Gulay Giray, Beata Zimowska, Ahmet Asan. Airborne mycotoxigenic fungi in Türkiye and Poland. ~50 p.

Abstract—There is increasing concern about exposure to airborne fungi. Research on mycotoxins shows that just as airborne fungal spores are everywhere in our environments, so too are their metabolic products. Mycotoxins with their cytotoxic, genotoxic, mutagenic, and teratogenic properties are persistent threats to human and animal health. Assessment of fungal exposure is notoriously challenging due to the numerous factors that contribute to the variation of fungal concentrations in environments. This paper reviews the homogeneity in the fungal species composition of these bioaerosols on a large geographical scale and the different drivers that shape these fungal communities which still remain unclear yet seem to be strongly governed by geographical location. Species reported from Türkiye and Poland representing *Absidia, Actinomucor, Alternaria, Aspergillus, Cladosporium, Emericella, Eupenicillium, Eurotium, Fusarium, Gibberella, Microdochium, Mucor, Paeicilomyces, Penicillium, Rhizomucor, Rhizopus, Stemphylium, Talaromyces,* and *Ulocladium* are listed with nomenclatural authorities, synonyms, and references.

Key words—airborne fungi, fungal communities, mycotoxicity



Didymium dictyosporum sp. nov.
(Lizárraga & Moreno— Fig. 1, p. 473)